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Lieut.-Col. C. W. THOMAS,

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TRANSACTIONS

OF

THE CERAMIC SOCIETY

INCLUDING

THE REFRACTORY MATERIALS SECTION.

Founded in 1900 as "The North Staffordshire Ceramic Society,"
and continued from 1903 to 1916 as
"The English Ceramic Society."

VOLUME XXI.—SESSION 1921-22.

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RULES.

(Subject to modification by recommendations from the Refractory Materials Section).

1.—The Society shall be called THE CERAMIC SOCIETY. It shall comprise a special section dealing with Refractory Materials.

2.—The object of the Society shall be the discussion of all subjects relating to the industries connected with ClayWorking and Refractory Materials.

3.—Persons desirous of membership shall be proposed and seconded by two Members of the General Meeting, and they are then eligible for election at the next Committee Meeting.

4.—The Society shall be governed by a President, Vice-Presidents and Council, a Librarian, a Secretary, and a Treasurer. The Officers shall be elected at the last General Meeting of each Session, and hold office until the last General Meeting of the ensuing Session, when they shall be eligible for re-election. Among the Vice-Presidents shall be included all past Presidents who are subscribing members of the Society. A Chairman of Council shall be appointed by the Committee.

4a.—The Council shall consist of officers, Ex-Presidents, and twelve members, of whom four shall resign each year, the retiring members to be eligible for re-election.

4b.—Two additional members of the Council, one of whom will also act on the Publication Committee, shall be elected by the Federation of Pottery Manufacturers.

5.—The headquarters of the Society shall be the Central School of Science and Technology, Stoke-on-Trent.

6.—The Meetings shall be fixed from time to time as arranged by the Sectional Committees. At Stoke-on-Trent the Meetings during the Session are usually held at 7-30 p.m. on the second Monday of the month.

7.—The annual subscription shall be payable in advance, and shall be fixed from time to time by the Committee (25/- for 1920-21). Members of the Society who have paid their annual subscription receive a copy of the TRANSACTIONS free.

8.—A firm can join the Society by paying an annual subscription of two guineas. For this subscription the attendance at each meeting shall be limited to three members of the firm, and one copy of the TRANSACTIONS will be supplied free annually.

9.—New members shall pay an entrance fee of one guinea.

10.—Students may be elected to Student Memberships without paying an entrance fee. Their subscription shall be 5/-, and will entitle them to attend the meetings, but no TRANSACTIONS will be supplied. After twelve months membership, a Student can be elected to full membership without payment of entrance fee. The Council shall decide whether a person is eligible for a Student Membership.

11.—Notification of meetings shall be sent by post to each member in Great Britain with the name of the subject of the paper for discussion.

12.—In the discussions arising upon any paper, no speaker shall occupy more than ten minutes, or make more than one speech, except by the permission of the Chairman.

13.—Any property of the Society lent to members must be returned within a week.

14.—Any member promising a paper and failing to keep his appointment shall himself provide a substitute.

15.—The Society shall have the prior right of publication of all papers read before it for a period of three months.

RULES—*Continued.*

16.—Authors must send their papers to the Society before or immediately after the communication has been read. If received in time the paper may be printed in time for the meeting. The official receipt of any paper will be dated from the time it is received by the Secretary.

17.—Members may obtain one copy of each of the back numbers of the TRANSACTIONS at subscription rates, providing they are for their own personal use, and that the number in stock be over 18.

18.—Members who are three years in arrear with their subscriptions shall be informed by means of a printed notice, and if the arrears are not paid within a month their names shall be struck off the list. *New Members are put on the list of members when their subscriptions have been paid.*

19.—A member of the Society may introduce a visitor to an ordinary meeting. A visitors' book is kept to show what non-members are present, and by whom they are introduced. The names of the visitors are read out by the Chairman at the opening of the same meeting.

20.—No alteration or addition to the above Rules shall be made except notice be given in General Meeting, and passed by the ensuing General Meeting. Ten to form a quorum.

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COUPAR, A., Bassilow Farm, Fenton, Stoke-on-Trent .. (1914-15)

COX, PAUL E., Dept. of Ceramic Engineering, Iowa State College, Ames, Iowa, U.S.A. .. .. (1912-22)
CRAWFORD, GEO., 11, Strathattan Crescent, Douglas, I.O.M. (1916-17)
CRONSHAW, Dr. H. B., Technical Institute, Brierley Hill, South Staffs. .. .. (1920-21)
CROW, ROBERT, Cruffell, Marraville, Melbourne, Australia (1918-19)
CULLINAN, D., Olifants Fontein, Transvaal, S. Africa .. (1921-22)
CULLINAN, R. V., c/o Box 286, Johannesburg, S. Africa .. (1913-14)
CUMING, N. F., c/o Cuming, Smith & Co., Ltd., 65, William Street, Melbourne, Australia .. .. (1921-22)
CYPLES, W. H., Trentham Road, Longton .. .. .. (1906-07)

DAVIDSON, J. H., M.Sc., Messrs. Wood Bros., Glass Co., Ltd., Pontefract Road, Barnsley. .. .. (1903-04)
DAVIE, C., Messrs. N. B. Allen & Co., Ltd., Hirwain, South Wales .. .. (1917-18)
DAVIS, TURNBULL & Co., 4 & 5, Prudential Buildings, Sheffield .. .. (1920-21)
DAVISON, J. A., Porthill, Stoke-on-Trent .. .. .. (1905-06)
DEB, S., 45, Tangra Road, Calcutta, India .. .. .. (1918-19)
DEELEY, J. H. A., 16, Baylie Street, Stourbridge .. (1912-13)
DENNIS, F. W., Holly Cottage, Ricardo Street, Dresden .. (1911-12)
DERBYSHIRE SILICA FIRE BRICK Co., Friden Station, Hartington, near Buxton .. .. (1921-21)
*DEVEREUX, P. S., c/o The British Abrasive Wheel Co., Ltd., Tinsley, Sheffield .. .. (1912-13)
DUNSMUIR, G., c/o Hillview, Bonnybridge, Stirlingshire .. (1916-17)
DODD, W. H., 52, Eaton Street, Hanley .. .. .. (1909-10)
DOLBY, W. J., 20, Gordon Street, Hartshill, Stoke-on-Trent.. (1920-21)
DONALD, W., 16, Lilybank Gardens, Glasgow, W. .. .. (1910-11)
DOUGALL, JAMES & SONS, Ltd., Firebrick Works, Bonnybridge, Stirlingshire .. .. (1916-17)
DOUGLAS FIREBRICK Co., Ltd., Kilwinning .. .. (1916-17)
DRESSLER TUNNEL OVENS, Ltd., Argyle Works, Carter's Crossing, Fenton .. .. (1916-17)
DRESSLER, PHILIP, 1551, East Boulevard, Cleveland, Ohio, U.S.A. .. .. (1918-19)
*DUFFIELD, F., L, The Derbyshire Basic Co., Ltd·, 99 Pinstone Street, Sheffield .. .. (1921-22)
DUNN, F. T., Messrs. The Henry Richards Tile Co., Tunstall, Stoke-on-Trent .. .. (1906-07)
*DUNN, J. T., D.Sc., F.I.C., Public Analysts' Laboratory, 10, Dean Street, Newcastle-on-Tyne .. .. .. (1916-17)

EARDLEY, DONALD, 5, Whitfield Avenue, Westlands, Newcastle, Staffs. .. .. (1920-21)
EDWARDS, A. O., c/o The Yorkshire Refractories Co., Ltd., 27, Waterdale, Doncaster .. .. (1917-18)
EDWARDS C. .. .. (1914-15)
EDWARDS, J. C., Terra Cotta Works, Ruabon .. .. (1921-22)
EDWARDS, W. H., Park Lane, Fenton, Stoke-on-Trent .. (1921-22)
EGLINTON MAGNESITE BRICK Co., Ltd., 45, Renfield St., Glasgow .. .. (1917-18)
ELLAND FIRECLAY Co., Ltd., Calder Fireclay Works, Elland (1916-17)
ELLIS, THOS., Penwyllt, near Neath .. .. (1916-17)
ELEY, ERNEST E., 15, Lord Street, Basford, Stoke-on-Trent (1920-21)
*EMERY, W., 7, Catherine Street, May Bank, Staffs. .. .. (1902-03)
ENDELL, K. Dr., Berlin Steglitz, Breitestrasse 3, Germany.. (1920-21)
ETCHELLS, H., 56, Westwood Road, Sheffield.. .. .. (1917-18)
EVERITT, CHARLES KINGSTON, c/o Edgar Allen & Co., Ltd., Imperial Steel Works, Sheffield .. .. .. (1916-17)

FAILL, JAMES, 146, West Regent Street, Glasgow .. .. (1916-17)
FARNLEY IRON Co., Ltd., Farnley, near Leeds .. .. (1916-17)
FEARNSIDES, W. G., 10, Silver Birch Avenue, Fulwood, Sheffield.. .. .. (1916-17)
FERN, E. R., School of Art, Bombay .. .. (1906-07)
*FIELDING, A., Devon Pottery, Stoke-on-Trent .. .. (1902-03)
FIELDING, R., Devon Pottery, Stoke-on-Trent .. .. (1906-07)
FINN, R., 2, Eaton Street, Hanley .. .. (1920-21)
FLETCHER, C. G., Highbury, Chadfield Road, Duffield, near Derby .. .. (1917-18)
FOLEY, F. D., Loch Lomond Road, St. John's, N.B., Canada (1917-18)
FORD, SAMUEL & Co., Lincoln Pottery, Burslem .. .. (1921-22)
FOSTER, HENRY & Co. Ltd., Backworth, Newcastle-on-Tyne (1916-17)
*FOSTER, J. E., 48, Gilman Street, Hanley .. .. .. (1909-10)
*FOX, W. G., 44, Riseley Road, Hartshill, Stoke-on-Trent .. (1912-13)
FOXWELL, G. E., 70, Steade Road, Sharrow, Sheffield .. (1916-17)
FRANCEY, D. M., c/o The Ridge Roasting Furnace and Engineering Co., 2, Great Winchester Street, E.C. 2 .. (1918-19)
FREEMAN, Dr. LUDFORD, Abbotsthorpe, Carnarvon Road, Redland, Bristol .. .. (1914-15)
FUJU, Y., c/o Japan Steel Works, Muroran, Hokkaido, Japan (1918-19)
FULPER, W. H., c/o The Fulper Pottery Co., Flemington, N.J., U.S.A. .. .. (1910-11)

GARDNER, W. J., c/o The Meltham Silica Brick Co., Ltd., Meltham, near Huddersfield.. .. .. (1916-17)
GARDNER, W. T., F.C.S., 14, Beechwood Avenue, Kew Gardens, London, S.W. .. .. (1918-19)
GATENSBURY, H. R., Atlas Foundry, Victoria Road, Hanley (1913-14)
GIBBONS, Ltd., Dibdale Works, Dudley .. .. .. (1916-17)
GIBSON, H. M., c/o The A. Y. Dinas Silica Brick Co., Ltd., 37, Lady Street, Kidwelly, S. Wales .. .. .. (1916-17)
GIBBS, A. E., 1006, Widner Buildings, Philadelphia, Pa., U.S.A. .. .. (1918-19)
GIBSON, J., The Laboratory, Glengarnock Works, Glengarnock (1917-18)
GIBSON, W. F., 18, Bushy Park, Totterdown, Bristol .. (1909-10)
GILL, W. R., Cleveland Villa, Castleford, Yorkshire.. .. (1909-10)
GIMSON, J. F., 69, Fountain Square, Fenton, Stoke-on-Trent (1920-21)
GIPP, H. W., c/o Electrolytic Zinc Co. of Australia, Risdon Road, Hobert, Tasmania .. .. (1918-19)
GLASS RESEARCH ASSOCIATION, The, 50, Bedford Square, London, W.C. 1. .. .. (1920-21)
GLENBOIG UNION FIRECLAY Co., Ltd., Glenboig, Scotland (1916-17)
GLEAVES, E., Alsager House, Marsh Avenue, Wolstanton, Stoke-on-Trent .. .. (1920-21)
GLOVER, SAMUEL, F.R.M.S., Olive Mount, St. Anns, St. Helens .. .. (1916-17)
GODDARD, J. V., Trentham .. .. (1905-06)
GODDARD, A. H., c/o Messrs. G. L. Ashworth Bros., Ltd., Hanley .. .. (1918-19)
GOODWIN, F. T. H., Hollydean, Park Avenue, Longton .. (1910-11)
GODWIN, A. F., c/o J. Bourne & Son, Denby Pottery, Derby.. (1915-16)
GOODWIN, W. E., Watcombe House, 225, Waterloo Road, Burslem .. .. (1902-03)
GOODWIN, JOHN, Foley Works, Fenton, Stoke-on-Trent .. (1920-21)
GOSLING, JAS., Atlas Foundry, Victoria Road, Hanley .. (1913-14)
GOSS, W. H., Falcon Pottery, Stoke .. .. (1914-15)
GRAHAM, J. W., Ashley Villa, Lancaster Av., Newcastle Staffs. .. .. (1914-15)

GRAY, A. E., Glebe Works, Mayer Street, Hanley .. .. (1917-18)
GRAYSON, LOWOOD, J. & Co., Ltd., Deepcar, near Sheffield (1916-17)
GRAY, J., Auldhaven, Milngavie .. .. (1918-19)
GREAVES-WALKER, A. F., Box 1122, Pittsburgh, Pa, U.S.A. .. .. (1920-21)
GREEN, A. T., 225, High Lane, Burslem, Stoke-on-Trent .. (1917-18)
GREEN, G. D., 700, Oak Hill, Stoke-on-Trent .. .. .. (1921-22)
GREEN, J. C., 49, Bromley Road, Kingswinford, Staffs. .. (1911-12)
*GREEN, S. A., Brampton Hill, Newcastle, Staffs. .. .. (1905-06)
GREGORY, C., Newfield, Willington, Co. Durham .. .. (1916-17)
GREGORY, J. G. & SON, Friars Street, Newcastle, Staffs .. (1921-22)
GREGORY, REDDISH & Co., Ltd., Silica & Firebrick Works, Deepcar, near Sheffield .. .. (1916-17)
GREGORY, T. W. D., Kinross, Trentham, Stoke-on-Trent .. (1906-07)
GRICE, E., 21, Station Road, Meir, Longton, Staffs. .. .. (1913-14)
GRIMWADE, C. D., Fairlands, Trent Vale, Stoke-on-Trent .. (1918-19)
GRIMWADE, L. L., Ashley, near Market Drayton .. .. (1906-07)
GRINDLEY, W. H., Woodland Pottery, Tunstall .. .. (1906-07)
GRIFFITHS, F. G., Quarter Denny, Stirlingshire .. .. (1918-19)
GROCOTT, F. J., 75, Shenstone Street, Edgbaston, Birmingham .. .. (1917-18)
GROCOTT, W., 75, Shenstone Road, Edgbaston, Birmingham (1918-19)

HADFIELD, SIR ROBERT, F.R.S., D.Met., D.Sc., 22, Carlton House, Terrace, London, S.W. .. .. .. (1916-17)
HAGUE, A. P., The Rookery, Dranfield, near Sheffield .. (1920-21)
HALL, HY., The Bungalow, Botteslow, Hanley .. .. .. (1912-13)
HALL, J. & Co., Stourbridge .. .. (1916-17)
HAMILTON, J., Ideal Pottery, Trenton Potteries Co., Trenton, U.S.A. .. .. (1906-07)
HAMILTON, J. D., c/o R. Muir & Co., Ltd., Armadale Station Linlithgowshire .. .. (1917-18)
HAMILTON, WILLIAM, 93, West George Street, Glasgow .. (1917-18)
HAMMOND, PERCY, Newbridge House, Bollington, Macclesfield .. .. (1916-17)
HAMMOND, WILLIAM, Jevington, Bollington, Macclesfield (1916-17)
HAMPTON, T. E., Eastwood Marl Works, Hanley .. .. (1908-09)
HANCOCK, E. A., Kepax, Worcester .. .. (1916-17)
HANCOCK, F., Ford Street, Shelton, Stoke-on-Trent.. .. (1902-03)
HANCOCK, W. C., B.A., F.I.C., 60, Greek Street, Soho Square, London, W.1 .. .. (1917-18)
HARBORD, F. W., 16, Victoria Street, London, S.W. .. (1916-17)
HARDING, F. W., 6, Hassell Street, Hanley .. .. .. (1921-22)
HARRISON, A. C., Bath Street, Hanley .. .. .. (1910-11)
HARRIMAN, WM., & Co., Ltd., 51, Westgate Road, Newcastle-on-Tyne .. .. (1917-18)
HARRINGTON, T. H., 55, Stanley Street, Tunstall .. .. (1913-14)
HARRISON, T. S., May Place, Newcastle, Staffs. .. .. (1921-22)
HARTLEY, E., 41, Llanthewy Road, Newport, Mon... .. (1917-18)
HARTLEY, H. L., Castleford Pottery, Castleford, Yorks .. (1917-18)
HARTMANN, M. L., The Carborundum Co. Niagara Falls, N.Y., U.S.A. .. .. (1921-22)
HARVEY, G., 78, Baskerville Road, Hanley .. .. .. (1921-22)
HASSALL, W., Tresco House, Woodville, Burton-on-Trent (1920-21)
HAUNCHWOOD BRICK & TILE Co., Ltd., Nuneaton .. (1921-22)
HAWTHORN, S., Mona House, Congleton, Cheshire.. .. (1905-06)
HAWTHORN, H., Morfa, Woodland Avenue, Wolstanton .. (1910-11)
HAWLEY, E., Woodland Cottage, Blurton, Staffs. .. .. (1914-15)
HAWLEY, ERNEST, c/o Messrs. Hawley & Jackson, Longton (1913-14)

HAWLEY, W. S., Fairmont, Sunny Bank Road, Newcastle, Staffs. .. .. (1908-09)
*HEATH, A., 61, Bethesda Street, Hanley .. .. .. (1900-01)
HEATH, B. C., St. Edmunds Avenue, Porthill, Staffs. .. .. (1921-22)
HEATH, C. H., High Street, Woodville, near Burton-on-Trent (1915-16)
HEATON, J., Ravenhead, St. Helens .. .. (1916-17)
HEATON, WM., Ravenhead Brick Co., Upholland, near Wigan (1917-18)
HENDERSON, H. B., 1538, N. High St., Columbus, Ohio, U.S.A. .. .. (1911-12)
HENDERSON, J. D., c/o The Anglo-Greek Magnesite Co., 24, Finsbury Square, London, E.C. .. .. (1917-18)
HEPWORTH IRON Co., Ltd., Hazlehead, near Sheffield .. (1916-17)
HEYS, F. W., Hydro., Kilmacolm, Scotland .. .. .. (1921-22)
HEWITT, A. E., Easedale, Trentham, Stoke-on-Trent .. (1912-13)
HEWITT, F. G., 6, Boughey Street, Stoke-on-Trent .. .. (1918-19)
HEWSON, GEO. W., Grasmere, Field Terrace, Jarrow-on-Tyne (1917-18)
HICKMAN, & Co., Fireclay Works, Stourbridge .. .. (1916-17)
HIGGINS, F. W., Carborundum Co., Ltd., Trafford Park, Manchester .. .. (1918-19)
HILL, F. W., c/o Reliance Firebrick Pottery Co., Chanch, P.O. Baraker, E.I.R., Bengal, India .. .. .. (1917-18)
HILL, WESTLAKE & Co., Ltd., 8 Gloucester Sq., Southampton (1920-21)
HIMLEY FIRE & RED BRICK Co., Ltd., near Dudley .. (1916-17)
HINCHLIFFE, HERBERT, Bullhouse Colliery, Penistone, Sheffield .. .. (1917-18)
HIND, S. R., Central Science School, Victoria Road, Stoke-on-Trent .. .. (1918-19)
HOBBS, W. E., Dyserth, Flintshire .. .. (1916-17)
HODSON, G. A., c/o The Hathern Station Brick & Terra-Cotta Co., Ltd., Loughborough .. .. (1908-09)
HOLGATE, A., Bunyip, Victoria, Australia .. .. .. (1918-19)
*HOLDCROFT, A. D., Bradwell Lane, Wolstanton .. .. (1902-03)
*HOLDCROFT, J. P., Bradwell Lane, Wolstanton .. .. (1902-03)
HOLLINSHEAD, T., The Elms, Penkhull, Stoke-on-Trent .. (1906-07)
HOLLOWAY, L. J., ... (1920-21)
HOPE, G. W., The Dingle, Fing ringhoe, Colchester .. (1920-21)
HOPE, H., Liverton, near Newton Abbott, Devon .. .. (1907-09)
HOULDSWORTH, H. S., 10, Rydal Terrace, Heckmondwicke, Yorks .. .. (1921-22)
HOWELL, C. G., 90, Leonard Road, Birches Head, Hanley .. (1916-17)
HOWELL, W. E., 41, Sneyd Terrace, Burslem .. .. .. (1915-16)
HOWLETT, S. & J., 23, Broom Street, Hanley .. .. (1918-19)
HOWIE, F. C., Hurlford, Fireclay Works, Kilmarnock .. (1916-17)
HOWSON, R. G., c/o Messrs. G. Howson & Sons, Limited, Hanley .. .. (1907-08)
HUGHES, F. S., Opal China Works, Fenton, Staffs. .. .. (1909-10)
HUNT, PERCY, Whiteley Cottage, Marehay, Derbyshire .. (1921-22)
HURLL, Ltd., P. & M., 144, West Regent Street, Glasgow .. (1917-18)
HUTTON, R. S., D.Sc., Castle Hill, High Wycombe, Bucks .. (1916-17)

JACKSON, G. J., Thanet House, Strand, W.C.2 .. .. (1917-18)
JACOBSEN, CARL, Malmogade 7, Copenhagen, Denmark
JACKSON, E. W., F.I.C., Godrevy, Saltburn-by-the-Sea .. (1918-19)
JAMES, W., Grimwades, Ltd., Winton Pottery, Stoke-on-Trent (1921-22)
JEFFREY, Dr. J. A., c/o Champion Porcelain Co., Detroit, Mich., U.S.A. .. .. (1917-18
JENKINSON, W., The Edinburgh & Leith Flint Glass Co., Edinburgh .. .. (1916-17)
JEPPSON, G. N., 41, Burncoat Street, Worcester, Mass., U.S.A. .. .. (1912-13)
JOHNSON, A. S., c/o Messrs. Alfred Meakin, Ltd., Tunstall.. (1909-10)

JOHNSON, S. Ltd., Brittania Pottery, Burslem, Stoke-on-Trent .. .. (1920-21)
JOHNSTONE, T. B., Park House, Eastfield Park, Weston-Super-Mare .. .. (1918-19)
JOHNSON, E., c/o Messrs. W. Boulton, Ltd., Navigation Rd., Burslem .. .. (1909-10)
JOHNSON, H., Tile Manufacturer, Highgate Tile Works, Tunstall .. .. (1906-07)
JOHNSON, J., Talke and Alsager Road, Alsager .. .. (1912-13)
JOHNSON, R. L., Oulton Rocks, Stone, Staffs... .. .. (1912-13)
JOHNSON, W. P., B.Sc., Foundry Lane, Wallheath, near Dudley .. .. (1910-11)
JOHNS, C., 404, Pitsmoor Road, Sheffield .. .. .. (1917-18)
JONES, A. B., Junr., Grafton Works, Longton .. .. .. (1914-15)
JONES, A. G., Lynton, Trentham, Staffs. .. .. .. (1909-10)
JONES, A. G. H., Heath House, Uttoxeter .. .. .. (1905-06)
JONES, CHARLES, Heatherfield, Bwlchgwyn, near Wrexham (1916-17)
JONES, CHESTER H., 1570, Old Colony Buildings, Chicago, U.S.A. .. .. (1921-22)
JONES, E. A., Glendene, Stallington Road, Blythe Bridge .. (1903-04)
JONES, F., Afanlea, Stone Road, Longton .. .. .. (1908-09)
JONES, GEO., & SONS, Ltd., Crescent Pottery, Stoke-on-Trent (1921-22)
JONES, L., Southwood, c/o Messrs. Southwood, Jones & Co., Danycraig Works, Risca, Monmouth .. .. .. (1916-17)
JONES, N. L., c/o J. & G. Meakin, Ltd., Hanley .. .. (1914-15)
*JONES, R. H. H., Riversdale, Keyberry Road, Newton Abbot (1900-01)
JONES, Sir W. J., Woodhall-Duckham & Jones, 52, Grosvenor Gardens, Westminster, S.W.,1 .. .. .. (1916-17)
JONES, W. R., 3, Lenches Bridge, Pensnett, near Dudley .. (1921-22)
JONES, W. R. D., University College, Cardiff .. .. .. (1921-22)

KEELING, F. A., c/o Messrs. Keeling & Walker, Stoke-on-Trent .. .. (1906-07)
KEELING, J., c/o Keeling & Co., Dalehall, Burslem .. .. (1906-07)
KEELING, G. A., Brown Edge Road, Stockton Brook, Stoke-on-Trent .. .. (1918-19)
KENT, H., 4, The Croft, Tenby .. .. (1918 19)
KENT, W. F., 72, Leonard Street, Burslem .. .. .. (1903-04)
KENT, W., c/o. Messrs. Taylor Tunnicliff & Co., Hanley, Stoke-on-Trent .. .. (1920-21)
KILNER, N. S., Hepworth Chambers, Briggate, Leeds.. .. (1918-19)
KIRKLAND, H. S., Albion Pottery, Etruria, Stoke-on-Trent (1906-07)
KLEIN, CARL, A., 4, Brimsdown Av., Enfield Highway, Middlesex .. .. (1915-16)
KNIGHT, W. C., Westholme, Barnfields, Penkhull, Stoke-on-Trent .. .. (1908-09
KREHBIEL, J. F., 168E, Lake view Avenue, Columbus, Ohio, U.S.A. .. .. (1917-18)

LAMPLOUGH, F. E., M.A., c/o Messrs. Chance Bros. & Co., Ltd., Glass Works, near Birmingham .. .. .. (1918-19)
LANCASTER, E., Lyndhurst, Trentham .. .. .. (1914-15)
LAX, F., Albert Glass Works, Hunslet, Leeds .. .. .. (1917-18)
LEACH, C. A., Padeswood, Weston Coyney, Stoke-on-Trent.. (1912-13)
LEATHER, J. P., Gas Works, Burnley .. .. (1916-17)
LEE, L. W., c/o Farmer & Chapman, Caledonian Works, Bilston (1918-19)
LEEDS FIRECLAY Co., Ltd., Wortley, Leeds.. .. .. (1916-17)
*LEESE, A., 81, Vivian Road, Fenton, Staffs. .. .. .. (1900-01)
LEIGH, A. K., Cranbourne, Oulton Cross, Stone, Staffs. .. (1914-15)
LEIGHS, T. J., 20, Clarke Street, Shelton, Stoke-on-Trent .. (1921-22)
LESSING, R., PhD., The Laboratory, Southampton House, 317 High Holborn, London .. .. (1910-11)

LEWIS, E. H., The Green, Wishaw, Scotland .. .. .. (1917-18)
LILLESHALL (The) Co., Ltd., Priors Lee Hall, Shifnal, Salop (1916-17)
LILLIBRIDGE, H. D., c/o American Encaustic Tiling Co., Ltd. Zanesville, Ohio, U.S.A. .. .. (1916-17)
LINDOP, R. C., 41, Grove Road, Fenton.. .. .. .. (1913-14)
LINSTRUM, T., Peacocks Bdg., 23, Park Row, Leeds.. .. (1917-18)
LLOYD, HORACE, Messrs. N. B. Allen & Co., Ltd., Hirwain, South Wales .. .. (1917-18)
LLOYD, W. J., Rothesay, King's Avenue, Wolstanton .. (1915-16)
LLOYD, T. H., c/o The Pure Bone Phosphate Co., 27, Kirkgate, Newark .. .. (1918-19)
LOCKHART, D. B., Victoria Pottery, Pollokshaws, Glasgow (1918-19)
LOMAX, J. R., 327, Bury Road, Bolton.. .. .. .. (1917-18)
LOUDON, JOHN, Loudon & Russell, Ltd., Allanton Fireclay Works, Newmains, Scotland.. .. .. (1917-18)
LOVATT, L. D., 79, Festing Street, Hanley .. .. .. (1916-17)
LOXTON, N. G., Leeds Fireclay Co., Burmantofts Works, Leeds .. .. (1918-19)
LUCAS, W. T., The Limes, Alsager .. .. (1921-22)
LYSAGHT, J., Ltd., Normanby Park Works, Scunthorpe, Lincs. (1918-19)

MACHIN, C. W., 65, Trentham Road, Longton .. .. (1914-15)
Mc KINLAY, PARKER, "Benhar," Otago, New Zealand .. (1921-22)
MacNEAL, C., Lloyds Bank Chambers, Fenton, Staffs. .. .. (1910-11)
MacWHIRTER, J., Elsinore, Milngavie, Scotland .. .. (1917-18)
McCORMICK, J., Dock Office, Hull, Yorks. .. .. .. (1917-18)
McCANCE, Dr. A., Westview, Uddingston .. .. .. (1918-19)
McDOWELL, J. S., 1800, Farmers Bank Buildings, Pittsburgh, U.S.A. .. .. (1918-19)
McNEILL, GEORGE, 181, Main Street, Bellshill, Lanarkshire.. (1918-19)
MALINOVSZKY, A., 22, N. Douglas Avenue, Belleville, Ill., U.S.A. .. .. (1916-17)
MALKIN, S., c/o The Malkin Tile Works Co., Burslem .. (1905-06)
MALKIN, W. F., Dalehall Mill, Burslem .. .. .. (1914-15)
MALKIN, J. R., The Limes, Porthill, Longport .. .. (1918-19)
MANCHESTER FURNACES Ltd., Ashton New Road, Manchester .. .. (1920-21)
MANSFIELD, F., 9, Red Cross Street, Liverpool .. .. (1918-19)
MARLOW, J. H., 19, The Villas, Stoke-on-Trent .. .. (1916-17)
MARSHALL, F. G., 65, Marine Parade, Sheerness-on-Sea, Kent .. .. (1911-12)
MARSHALL, F. J., 25, Marine Parade, Sheerness-on-Sea, Kent (1920-21)
MARTIN, GEOFFREY, Rosherville Court, Burch Road, Gravesend .. .. (1921-22)
MASON, ADAM & SONS, Ltd., Horwich, Lancashire.. .. (1916-17)
*MAYER, E. W. T., 11, Westwood Road, Wolstanton.. .. (1914-15)
MAW, J. S., 13, St John's Hill, Shrewsbury .. .. .. (1921-22)
MEADE, ALWYNE, Commercial Gas Co., Wapping, London, E. 1 .. .. (1916-17)
MEAKIN, J. & G., Ltd., Eagle Pottery, Hanley, Stoke-on-Trent .. .. (1918-19)
MEIR, J., 240, Waterloo Road, Burslem.. .. .. .. (1911-12)
MEIGH, N. .. .. (1920-21)
*MELLOR, J. W., D.Sc., Sandon House, Regent St., Stoke-on-Trent .. .. (1904-05)
MEREDITH, J., 42, Stanley Street, Tunstall .. .. .. (1911-12)
MEREDITH, L. Clenard, Blythe Bridge, Stoke-on-Trent .. (1918-19)
METCALFE, E. D., Nobel House, Buckingham Gate, London, S.W. 1 .. .. (1918-19)
MICHELSEN, H. C., 20, Essex Street, Strand, London, W.C., 2 (1921-22)
MICHIE, A. C., 12, Akenside Hill, Newcastle-on-Tyne .. (1910-11)

MIDDLETON FIRECLAY WORKS, Leeds .. .. .. (1916-17)
MILLS, F. E., Brentford Gas Co., Brentford, Middlesex .. (1921-22)
MITCHELL, JOHN, c/o A. Y. Dinas Silica Brick Co., Ltd., 142, Queen Street, Glasgow .. .. (1916-17)
MITCHELL, J. S., Hyland, Hargate Drive, Hale, Manchester (1917-18)
MOLLER, C. A., Vestergade, 33, Copenhagen, Denmark .. (1921-22)
MOMOKI, S., c/o Toyo Toki, Kwaisha, Shinozaki, nr. Kokura City, Japan .. .. (1916-17)
MONTGOMERY, ROBERT J., c/o Bausch & Lomb Optical Co., Co., Rochester, N.Y., U.S.A .. .. (1918-19)
MONTGOMERY, ALLAN W., 58, York Street, Glasgow .. (1918-19)
*MOORE, B., Draycott, Blythe Bridge, Stoke-on-Trent .. (1900-01)
MOORE, BERNARD, J., Hawthorns, Keele, Staffs .. .. (1913-14)
MOORE, C. H., 244, Fulwood Road, Sheffield .. .. (1917-18)
MOORE, CHRISTOPHER E., The Hurst, Hagley, Stourbridge (1921-22)
MOORSHEAD, T. C., 40-43, Norfolk St., Strand, London, W.C.2. (1921-22)
MORETON, WILLIAM P., c/o Messrs. Thos. Forrester & Sons, Ltd., Phœnix Works, Longton, Stoke-on-Trent .. .. (1921-22)
MORTON, JOSEPH, Ltd., Cinder Hill Fireclay Works, Halifax, Yorks. .. .. (1917-18)
MORRALL, F., 49, Kensington Road, Oakhill, Stoke-on-Trent (1917-18)
MOSS, G. H., 47, Heron Street, Fenton, Stoke-on-Trent .. (1920-21)
MOTTRAM, GEO. WM., 1, Montague Street, London, W.C. 1 .. (1916-17)
MOULTON, D.A., Iowa State College, Dept. of Ceramic Engineering, Ames; Iowa, U.S.A. .. .. (1918-19)
MOURITZEN, C. F., Calyx Paint Works, Lord Street, Perth, Western Australia .. .. (1920-21)
MYERS, E.M., Greycourt, Harpfields, Stoke-on-Trent .. .. (1921-22)
MYOTT, A., c/o Messrs. Myott, Son & Co., Cobridge, Burslem (1904-05)

NEGUS, W., 36, Bloomsbury Square, London, W.C. 1 .. (1918-19)
NEWBY, F. B., c/o Malkin Tile Works, Burslem, Staffs .. (1917-18)
NEWMAN, H. S., Sunnyside, Oxford Road, Basford Park, Stoke-on-Trent .. .. (1917-18)
NEW YORK PUBLIC LIBRARY, 476, Fifth Avenue, New York, U.S.A. .. .. (1921-22)
NICHOLSON, E. D., Park Issa, Oswestry .. .. .. (1918-19)
NIXON, WM., Mayfield, Weston Coyney, Stoke-on-Trent .. (1916-17)
NOBLE, E., Birch House, Worksop .. .. (1917-18)

OATES & GREEN, Ltd., Halifax, Yorks. .. .. .. (1916-17)
OAKES, W. c/o. Sand, Glass & Foundry Materials (Amalgamated) Ltd., 27, Waterdale, Doncaster .. .. .. (1920-21)
*ODELBERG, A.S. W., Gustafsberg Pottery, Gustafsberg, Sweden (1904-05)
OKURA, K., 22, Ipponmattsu, Azab, Tokyo, Japan .. .. (1915-16)
*OLSEN, B., The Villas, Stockton Brook, Stoke-on-Trent .. (1900-01)
ORMANDY, W. R., D.Sc., 18, Belsize Grove, Belsize Park, N.W. 3. .. .. (1917-18)
ORTON, E., Columbus, Ohio, U.S.A. .. .. (1903-04)
OUGHTIBRIDGE SILICA FIREBRICK WORKS, The Oughtibridge, Sheffield .. .. (1916-17)
OWEN, T. WILFRED, 4, Dukes Place, St. Georges, Shropshire .. .. (1920-21)

*PAGE, E. P., 123, Abbey Foregate, Shrewsbury .. .. (1904-05)
PAINE, W. H. C., Calder Fireclay Co., Coatbridge .. .. (1916-17)
PAINE, J. W. R., Calder Fireclay Co., Coatbridge .. .. (1918-19)
PARKER, W. B., F.I.C., 1, Murrey Road, Rugby .. .. (1918-19)
PARKINSON & SPENCER, Ambler Thorn Fireclay Works, Halifax .. .. (1916-17)
PARMELEE, C. W., Professor of Ceramic Engineering, University of Illinois, Urbana, Illinois, U.S.A. .. .. (1906-07)

PASS, R. H., West Rising, Onondaga Pottery Co., Syracuse, N.Y., U.S.A. .. .. (1920-21)
PEARSALL, W. H., c/o Mobberley & Bayley, Stourbridge .. (1916-17)
PEARSON, E. J. & J., Ltd., Fireclay Works, Stourbridge .. (1916-17)
PEARSON & Co., The Potteries, Whittington Moor near Chesterfield .... (1918-19)
POUNTNEY & Co., Ltd., The Bristol Pottery, Fishponds, near Bristol .. .. (1918-19)
PEREGRINE, C. R., 5555, Forbes Street, Pittsburgh, Pennsylvania .. .. (1917-18)
PERRY, PEARSON G. H., Portland House, Pedmore, nr. Stourbridge .. .. (1916-17)
*PERRY, T., 247, Campbell Road, Stoke-on-Trent .. .. (1910-11)
PICKFORD, HOLLAND & Co., Ltd., Eclipse Ganister Works, Sheffield .. .. (1916-17)
PICKFORD, R. J., Thornlea, Carmel Road, Darlington .. (1917-18)
PIKE, L. G., Wareham, Dorset .. .. (1912-13)
PIMBLE, A. V., West Street, Penkhull, Stoke-on-Trent .. (1918-19)
PINHEIRO DA SILVA, ISRAEL CARTHE, Minas Gerais, Brazil, South America .. .. (1920-21)
PITCAIRN, G., Fabrica-de-Loza, San Juan de Aznal-farache, Sevilla, Spain .. .. (1916-17)
PLANT, F., Stone Road, Longton .. .. (1912-13)
*PLANT, H. J., Rostherne, Park Avenue, Longton, Stoke-on-Trent .. .. (1902-03)
PLANT, J., Melbourne House, Stone .. .. (1912-13)
PODMORE, A. J., Consall Hall, Consall, Stoke-on-Trent .. (1916-17)
PODMORE, WM., Consall Hall, Consall, Stoke-on-Trent .. (1913-14)
POLGREAN, J. H., 183, Leek New Road, Burslem .. .. (1921-22)
POOLE, THOS., Cobden Works, Longton .. .. .. (1915-16)
POOLE, HORACE, 96, Chaplin Road, Longton .. .. (1916-17)
POWELL, W. H., 41, Plymouth Street, Monteclair, New Jersey, U.S.A. .. .. (1908-09)
PRESTON, D., 35, High Street, Bucknall, Stoke-on-Trent .. (1916-17)
PRICE, G., Clifton, Silverdale Road, Wolstanton, Staffs. .. (1908-09)
PRICE, J. T. & Co., Ltd., Stourbridge .. .. (1916-17)
PRICE, S. H., "Lag-na-ha," Porthill, Stoke-on-Trent .. .. (1912-13)
PRYOR, E. A. COAD, The National Physical Laboratory, Teddington, Middlesex .. .. (1917-18)

*RAMSDEN, C. E., Foley Colour Works, Fenton, Stoke-on-Trent (1902-03)
RAMSAY, A., Mount Savage, Md., U.S.A. .. .. .. (1908-09)
RANN, R. C., 14, Great George Street, Westminister, London, S.W. 1. .. .. (1918-19)
REDFERN & DRAKEFORD, Balmoral Works, Normacot, Stoke-on-Trent .. .. (1918-19)
REED, G. H., 1, Wear Street, Newfield, Willington, Co. Durham (1921-22)
RELIANCE FIREBRICK & POTTERY Co., Ltd., The (Andrew Yule & Co., Ltd., Agents), 8, Clive Row, Calcutta (1920-21)
REES, WALTER, J., Department of Refractory Materials, The University, Sheffield .. .. (1916-17(
RHEAD, F. H., Director, Research Dept., American Encaustic Tiling Co., Zanesville, Ohio, U.S.A. .. .. (1920-21)
RHEAD, T. F. E., 10, Malvern Road, Acocks Green, Birm'ham (1921-22)
REYNOLDS, G., Tachbroke House, Normacot.. .. .. (1903-04)
*RICHARDSON, A. G., "Linden," Oakville Avenue, High Lane, Burslem .. .. (1900-01)
RICHARDSON, GEO., 140, Pinnox Street, Tunstall .. .. (1913-14)
RICHARDSON, W. D., The Claycroft Mining and Brick Co., Shawnee, Ohio, U.S.A. .. .. (1906-07)

RIDGE, H. M., 2, Great Winchester Street, E.C. 2 .. .. (1917-18)
RIDGWAY, B. Bedford Works, Hanley .. .. (1913-14)
RIDGWAY, F. J., (H. Aynsley & Co.) Commerce Street, Longton, Stoke-on-Trent .. .. (1921-22)
RIES, H., Cornell University, Ithaca, New York .. .. (1911-12)
RIGBY, A., 164, Trentham Road, Penkhull, Stoke-on-Trent (1920 21)
RIGBY, J. H., Buccleuch Road, Longton .. .. .. (1921-22)
RILEY, HAROLD E., Tresco, St., Austell .. .. .. (1917-18)
ROBERTS, J. G., c/o Messrs. Shanks & Co., Barrhead, N.B (1904-05)
ROBERTS & MAGINNIS, Ltd., Trevor, Ruabon, N. Wales .. (1921-22)
ROBERTSON, F. L., (Capt.) M.C.; B.Sc., 17, Riddrie Knowes, Glasgow .. .. (1921-22)
ROBINSON, H. M., c/o Messrs. Minton & Co., Ltd., Stoke-on-Trent .. .. (1909-10)
ROBINSON, H. T., China Works, Shelton, Stoke-on-Trent .. (1917-18)
RODGER, WYLIE, 18, Charles Street, St. Rollox, Glasgow (1918-19)
ROSS, DONALD W., The Findlay Clay Pot Co., Washington, Pa, U.S.A. .. .. (1917-18)
ROWLEY, T. H., 63, Gilman Street, Hanley .. .. .. (1921-22)
*RUSSELL, FRANK, Highland Grove, Worksop .. .. (1916-17)
RUIZ, F., c/o Banco de Chile, 94, Gracechurch Street, London (1918-19)

SADLER, EDWARD, Newlands, Watlands Avenue, Wolstanton (1917-18)
SAILLY, PAUL, Compagnie Générale d'Electro-Céramique, 64, Rue Franklin, Ivry-Port, Seine, France .. .. (1917-18)
SANDLAND, T. H., Whitebridge, Newcastle Road, Stone, Staffs. .. .. (1917-18)
SANITER, E. H., Phoenix Special Steel Works, The Ickles, Sheffield .. .. (1916-17)
SANKEY, C. H., Wildcroft, Chislehurst, Kent.. .. .. (1916-17)
SATOH SHINZO, TOKIO ELECTRIC Co., Ltd., Kawaski, Kanagawa-Ken, Japan .. .. (1920-21)
SAXTON, C., 35, Bedford Street, Strand, London, W.C., 2 .. (1918-19)
SAYER, JAMES, Junr., Hill Crest, James St., Stoke-on-Trent (1912-13)
SCHURECHT, H. G., 141, Pacemount Road, Columbus, Ohio, U.S.A. .. .. (1918-19)
SOCIETE DES PRODUITS CERAMIQUES ET REFRACTAIRES, 4, Rue Blanche, Paris, ... (1918-19)
SCRIVENER, E. D., c/o Messrs. Taylor, Tunnicliff & Co., Eastwood, Hanley .. .. (1908-09)
*SCOTT, A., M.A., D.Sc., Central School of Science and Technology, Stoke-on-Trent .. .. (1917-18)
*SEARLE, A. B., The White Building, Sheffield.. .. .. (1907-08)
*SHAH, C. P., Sorab Dahal Tile Works, Than Road, Bombay.. (1913-14)
SHANKS, D., Raisdale, Barrhead, N.B. .. .. .. (1905-06)
SHAW, A. G., Whitebrick Brick Works, Darwen, Lancs. .. (1918-19)
SHENTON, R., c/o Messrs. Wedgwood & Co., Tunstall .. (1903-04)
SHEPPARD, P. N. F., 2, The Avenue, Beckenham, Kent .. (1917-18)
SHERLOCK, A., Winterton Pottery, High Street, Longton .. (1916-17)
SHERLOCK, W., Winterton Pottery, High Street, Longton .. (1921-22)
SHIRLEY, T. H. F., Walton Lodge, Stone, Staffs. .. .. (1921-22)
SILLARS, D., Bidston, Britannia Terrace, Saltburn-by-the-Sea (1918-19)
SIMPSON, T. A., Lyndhurst, Wolstanton .. .. .. (1914-15)
SIMPSON, T. G., 34, Elm Street, Cobridge, Stoke-on-Trent.. (1917-18)
SIMPSON, W. A., 27, Kensington Road, Oakhill, Stoke-on Trent .. .. (1916-17)
SIMPSON, E., Pynest Street, Shelton, Stoke-on-Trent .. (1918-19)
SINGH KRISHEN, c/o The Delhi Pottery Works, Rai Sina. Delhi, India .. .. (1921-22)
SMART, H. E., Mountain View, Kidwelly, Carmarthenshire.. (1916-17)

SMITH, H. PROCTER, Hawarden Bridge Steel Works, Shotton, Chester.. .. .. (1916-17)
SMITH, OLIVER, Lilac House, Old Hunwick, nr. Willington, Co. Durham .. .. (1916-17)
SMITH, F.R., Eastfield, Ironbridge, R.S.O., Salop .. .. (1902-03)
SNEYD COLLIERIES, Ltd., Burslem .. .. (1916-17)
SNOW, WILFRED, R., G.P.O. Box No. 525, Adelaide, South Australia .. .. (1918-19)
SOHO POTTERY Ltd', Elder Works, Cobridge, Stoke-on-Trent (1921-22)
SOLON, L. V., c/o American Encaustic Tile Co., Ltd., 16, East 40th Street, New York, U.S.A. .. .. (1915-16)
SOMERVILLE, W., The Cottage, Hindlow, Buxton .. .. (1916-17)
SOSMAN, R. B., 2801, Upton Street, Washington, D.C., U.S.A. .. .. (1918-19)
SOUTH METROPOLITAN GAS Co., 709, Old Kent Road, London, S.E. 15 .. .. (1917-18)
SPEIRS, C. W., The Morgan Crucible Co., Battersea Works, London .. .. (1916-17)
STAFFS. CROWN COLOUR Co., 5, Lord Street, Basford .. (1918-19)
*STANLEY, WALTON, 8, Stoke Road, Shelton .. .. .. (1911-12)
STANLEY, CYRIL, Lyndhurst, Shelton, Stoke-on-Trent .. (1921-22)
*STANYER, A., 24, Jenkins Street, Burslem .. .. .. (1903-04)
STANWAY, P. W., Clive House, Clive Street, Shelton .. (1921-22)
STATON, A. D., 37, King's Avenue, Wolstanton, Stoke-on-Trent .. .. (1920-21)
STEAD, J. E., D.Sc., 11, Queen's Terrace, Middlesbro' .. (1916-17)
STEELE, H. L., Regent Road, Hanley .. .. .. (1912-13)
STEIGER, EUGENE, ... (1921-22)
STEIN, JOHN G. & Co., Ltd., Bonnybridge, Scotland .. (1916-17)
STEPHENS, ALFRED, Broomhill, Kidwelly .. .. .. (1916-17)
STEVENSON, H. W., Montrose, 1st Avenue, Porthill .. (1913-14)
STEVENSON, SAMUEL, 59, Elm St., Cobridge, Stoke-on-Trent (1921-22)
STOTT, VAUGHAN H., 9, Elmers Drive, Teddington, Middlesex.. .. .. (1920-21)
STOURBRIDGE REFRACTORIES Co., Ltd., Pensnett, nr. Dudley .. .. (1916-17)
STOVER, E., 474, West State Street, Trenton, U.S.A. .. (1903-04)
STRINGER, G. E., Wynberg, Newcastle Road, Stone, Staffs. (1918-19)
STUBBS, R., Church Terrace, Blythe Bridge .. .. .. (1920-21)
SURR, M. M., Serpentine Lane, Calcutta .. .. (1922-23)
SUTHERLAND, W. FRANK, 79, Normandy Buildings, Toronto, Ont., Canada .. .. (1918-19)
SWIFT & NETHERWOOD, Lepton, Fenay Bridge .. .. (1921-22)
SWINDEN, THOMAS, 26, Oak Hill Road, Nether Edge, Sheffield (1916-17)
SWINNERTONS, Ltd., Vulcan Pottery, Hanley, Stoke-on-Trent (1918-19)

TAMS, H., Wharf Street, Longton, Stoke-on-Trent .. .. (1913-14)
TARRANT, W. G., Ltd., Byfleet, Surrey .. .. (1921-22)
TAYLOR, A. B. (Miss), Dunstable House, Sheen Road, Richmond .. .. (1918-19)
TAYLOR, F. E., Trentham, Staffs. .. .. (1913-14)
TAYLOR, J. F., Trentham, Staffs. .. .. (1915-16)
TEALE, JAMES W., 33, Grange Road, Brook Lane, Chester .. (1920-21)
THOMAS, C. W., c/o Messrs. E. J. & J. Pearson, Ltd., Brierley Hill, S. Staffs. .. .. (1903-04)
THOMAS, C. A. G., Clifton House, Old Swinford, Stourbridge (1921-22)
*THOMASON, W., Royal Doulton Potteries, Lambeth, London, S.E. .. .. (1909-10)
THOMPSON, H. H., 52, Lombard Street, Birmingham.. .. (1921-22)
THORLEY, P. S., Froghall Lime Works, Cheadle, Staffs. .. (1907-08)

THORLEY, J. P., 31, Newcastle Road, Shelton, Stoke-on-Trent .. .. (1920-21)
THRELFALL, C. R. F., c/o Timmis & Co., Stourbridge .. (1920-21)
THURSFIELD, W. T., 41, Stanley Street, Tunstall .. .. (1921-22)
TIDY, CHARLES J., 16, Amesbury Avenue, Streatham Hill, London, S.W. .. .. (1921-22)
*TIMMIS, G. H., Storrage House, Wribbenhall, Bewdley .. (1916-17)
TOOGOOD, H. J., The Poplars, Elland, Yorkshire .. .. (1918-19)
TOOTH, W. E., Claridge House, Woodville, Burton-on-Trent (1913-14)
*TOWNSEND, H., Mount Avenue, Hartshill, Stoke-on-Trent (1909-10)
TRAVIS, W. P., Church Street Chambers, Stourbridge .. (1916-17)
TREDDENICK, WM., 3, Primrose Hill, Newfield, Willington, Co. Durham .. .. (1921-1922)
*TURNER, F., Cranleigh, Brampton, Newcastle .. .. (1900-01)
TURNER, W. E. S., D.Sc., M.Sc., Department of Glass Technology, The University, Sheffield .. .. (1916-17)

UNITED COLLIERIES, Ltd., 109, Hope Street, Glasgow .. (1916-17)
UNIVERSITY OF WASHINGTON LIBRARY, Seattle, Washington .. .. (1920-21)
UNIVERSITY OF CALIFORNIA LIBRARY, Berkley, California, U.S.A. .. .. (1920-21)

VAUGHAN, A. J., Grant Street Colour Works, Burslem .. (1914-15)
VICKERS, A. E. J., 27, Lily Street, Wolstanton, Stoke-on-Trent .. .. (1918-19)

WADE, G., High Street, Burslem .. .. (1914-15)
WAGSTAFF, J. J., 51, Oulton Road, Stone .. .. (1921-22)
WALKER, E. E., The Australian Tesselated Tile Co., Ltd., Mitcham, Victoria Australia .. .. (1916-17)
WALKER, F. W., Art Tile Works, Beaver Falls, Pa, U.S.A. (1906-07)
WALKER, JOHN, The Gate Farm Fireclay & Firebrick Works, Kingswinford, near Dudley .. .. .. (1916-17)
WALLACE, Miss JANET A., B.Sc., 52, Kitchener Street, Motherwell .. .. (1917-18)
WALTON, C. J., Forsbrook, Stoke-on-Trent .. .. .. (1912-13)
WARBURTON, T. H., The Monk Bridge Iron & Steel Co., Ltd., Leeds .. .. (1916-17)
WARD, T. W., Endcliffe Vale House, Sheffield .. .. (1917-18)
WATERHOUSE, JAMES, Ltd., Soho Works, Wakefield .. (1916-17)
WATTISON, J. T. Rua da Restauraçaõ, 122, Porto, Portugal.. (1918-19)
WATKIN, E., 57, Yoxall Avenue, Hartshill .. .. .. (1916-17)
*WATKIN, H., Woodleigh, Porthill, Stoke-on-Trent .. .. (1900-01)
WATKIN, T., Harding Terrace, Sheppard St., Stoke-on-Trent (1904-05)
WATTS, A. S., Lord Hall, O.S.U., Columbus, Ohio, U.S.A. .. (1910-11)
WEATHERBY, W. H., c/o C. Tenant, Sons & Co., Ltd., 80/82, Merchants Exchange, Cardiff.. .. .. .. (1918-19)
WEBSTER, J. C., Bridge Pass, Victoria Road, Tunstall .. (1910-11)
WEBSTER, JAS., Lynve, Victoria Road, Tunstall .. .. (1913-14)
WEBSTER, J. T., Shallowford House, near Stone, Staffs. .. (1921-22)
WEDGWOOD, Miss A., The Woodhouse, Cheadle, Staffs. .. (1916-17)
WEDGWOOD, ERNEST, B., The Grove, Wolstanton.. .. (1916-17)
*WEDGWOOD, F. H., c/o Josiah Wedgwood & Sons, Ltd., Etruria, Stoke-on-Trent .. .. (1905-06)
WELLINGTON GAS Co., Courtney Place, Wellington, N.Z.
WELLS, J. H., 10, Glanbrydan Avenue, Uplands, Swansea.. (1916-17)
WENGER, A. F., Victoria House, Newcastle, Staffs... .. (1905-06)
WENGER, A. H., Trentham Priory, Staffs. .. .. .. (1902-03)
WENGER, F. E., The Hollies, The Brampton, Newcastle Staffs (1905-06)
WERNER, E. A. R., 174, Corporation Street, Birmingham.. (1920-21)
WHISTON, H. W., 12, Hollings Street, Fenton, Stoke-on-Trent (1920-21)

WHITELEY, A., 7, Glen Road, Netheredge, Sheffield.. .. (1917-18)
WHITFIELD, T. S., c/o The Cobridge Brick Co., Burslem .. (1905-06)
WHITELEY, J. H., 11, Cambridge Street, Saltburn, York. .. (1918-19)
WILD, ARTHUR, Hawthorn Dene, Hathersage .. .. (1916-17)
WILEMAN & Co., Foley China Works, Fenton, Stoke-on-Trent (1921-22)
WILKINSON, A. J., Ltd., Burslem, Stoke-on-Trent .. ..
WILLIAMS, C. P., M.Sc., Flwdwycet, Penrycae, Port Talbot (1916-17)
WILLIAMS, F. R., 1, Beaconfield Villas, Brighton .. .. (1902-03)
*WILSON, S. T., Park Works, Fenton, Staffs. .. .. .. (1904-05)
WITTON FIREBRICK Co., Ltd., Wear Valley Junction, near Darlington .. .. (1916-17)
WILKINSON & SON, S., Blackley Fireclay Works, Elland Yorks. .. .. (1916-17)
WILTSHAW, & ROBINSON, Carlton Works, Copeland Street, Stoke-on-Trent .. .. (1916-17)
WINKLE, L. H., Colonial Pottery, Stoke-on-Trent .. .. (1908-09)
WONG, W. W., 131, S. Broadway, Los Angeles, California, U.S.A. .. .. (1918-19)
WOOD, A. R., c/o Pilkingtons, Ltd., St. Helens, ... (1920-21)
*WOOD, H. E., Hillside, Hamil Road, Burslem.. .. .. (1900-01)
WOOD, H. F., The Uplands, Brampton, Newcastle, Staffs. .. (1911-12)
WOOD, ROBERT, Quarry House, Dudley, Worcestershire .. (1921-22)
*WOOLDRIDGE, F., Taylor, Tunnicliff & Co., Hanley .. (1905-06)
WORKINGTON IRON & STEEL Co., Ltd., Moss Bay, Workington .. .. (1916-17)
WORTHINGTON, F. S., 5, Havelock Place, Shelton, Hanley (1907-08)
WRAGG, THOS., & SONS, Storrs' Fireclay Works, Loxley, near Sheffield .. .. (1916-17)
WRAGG, THOS., & SONS, Swadlincote.. .. .. .. (1917-18)
WRIGHT, J. E., 153, Cauldon Road, Hanley .. .. .. (1914-15)
WRIGHT, W. T. & Co., Ltd., Sileby, near Loughboro' .. (1921-22)

The numbers in brackets denote the session of election.

Any change of postal address should be communicated to the Assistant Secretary,

A. RIGBY. Pottery Laboratory, Stoke-on-Trent.

Student Members.

BAILEY, W. E., 27, Buccleuch Road, Longton .. .. (1920-21)
BAILEY, W. M. Z., 5, Morley Street, Tunstall.. .. .. (1920-21)
BENNIE H. DOUGLAS, 15, Gordon Street, Hartshill, Stoke-on-Trent .. .. (1921-22)
BOWERS, J., 67, Albany Road, Birches Head, Hanley .. (1921-22)
BREEZE, T. H., New Street Stores, Hanley .. .. .. (1920-21)
BURTON, W., 50, Havelock Street, Stoke-on-Trent .. .. (1920-21)

DERRY, B. R., Hazelhurst, Blurton Road, Fenton .. .. (1920-21)

HARDING, F. W., 6, Hassall Street, Hanley .. .. .. (1920-21)
HEAP, J. W., 9, Morley Street, Tunstall .. .. .. (1920-21)

JONES, A. E., Lightwood Chase, Longton .. .. .. (1920-21)
JONES, STANLEY CARTLIDGE, 4, Westland Avenue, Newcastle, Staffs. .. .. (1920-21)

MACE, GEORGE, Hillesden, Caverswall Lane, Blythe Bridge.. (1920-21)
MEREDITH, W. DENNIS, 42, Stanley Street, Tunstall .. (1921-22)
MORRIS, J., 4, Foley Road, Longton .. .. (1920-21)

NEALE, J. R., Rushton Road, Cobridge, Stoke-on-Trent .. (1920-21)

PARTON, LEWIS, 22, Windmill Terrace, Smith Street, Hanley .. .. (1920-21)

ROTCHFORD, J., 39, Berdmore Street, Fenton .. .. (1920-21)
RIGBY, S., Church Street, Fenton .. ..

SHIPLEY, W., Kingsley, Stockton Brook, Stoke-on-Trent .. (1920-21)
STEVENSON, SPENCER, 30, Eagle Street, Hanley .. .. (1920-21)

WARRILOW, H., 7, Bennett Street, Burslem .. .. .. (1921-22)
WHITE, G. J. C., 290, Princes Road, Penkhull, Stoke-on-Trent
WILLDIGG, L. J., Bromley Hough, Garden Village, Stoke-on-Trent .. .. (1921-22)
WILSON, N., Duke Street, Fenton .. .. (1920-21)
WOOD, H. F., Uplands, Newcastle, Staffs. .. .. .. (1920-21)

Proceedings.—Session 1921-22.

General Meeting held in the Central Science School, Stoke-on-Trent, on Monday, 17th October, 1921. Mr. Cuthbert Bailey presided over an attendance of about 100. The following were nominated for membership of the Society :—Collective : The British Commercial Gas Association. Individual : Messrs. F. Mills, W. Clayton, R. E. Aulanier, F. L. Duffield, J. E. Benn, P. Hunt, A. P. Hague, F. W. Hays, C. McH. Brown, F. Loffil, J. J. Wagstaffe, W. Sherlock, W. D. Newby, R. G. Harris. Student : Messrs. H. D. Bennie, G. White, S. Rigby, W. Warrilow, B. Jackson, W. D. Meredith. Dr. Scott summarised a communicated paper sent by Messrs. W. J. Rees and W. Hugill, entitled, "A note on the Slag used in Tile making at Sarreguemines, Alsace." Mr. J. Percival Woolf gave two papers : (1) "The Use of Vaporized Oil Fuel ; (2) "Continuous Compensated Kilns with Oil Fuel," and the following members took part in the discussion : Messrs. C. Bailey, J. H. Marlow, W. Emery, J. H. Meredith, J. Williamson and Dr. J. W. Mellor.

General Meeting held in the Central Science School, Stoke-on-Trent, on Monday, 7th November, 1921. About 120 members were present and Mr. Ashley Myott presided. The following were proposed for membership : Collective : Messrs. Roberts & Maginnis, Ltd., Brunner, Mond & Co., Ltd., N. T. Wright & Co., Ltd., Swift & Netherwood. Individual : Messrs. T. C. Moorshead, W. H. Hewitt, J. H. Polgrean, W. R. D. Jones, L. Robertson, J. H. Andrew, D.Sc., G. Hankey Reed, W. Treddenick, F. Woodhead, W. Royall, E. Colclough, C. J. Chambers, Student : Messrs. J. Bowers, A. Johnson, D. Stevenson. Dr. A. Granger, of Paris, wrote accepting the Honorary Membership of the Society which was conferred on him at the London Meeting of the Refractory Materials Section. Mr. J. C. Farrant gave a paper entitled "Closed Circuit Grinding." Owing to shortage of time, it was impossible to have a full discussion on the paper, but brief remarks were made by Messrs. B. J. Moore, C. Bailey, W. E. Goodwin, F. Wooldridge, A. Fielding, C. D. Grimwade and W. Podmore.

General Meeting held on Monday, 12th December, 1921, in the Central Science School, Stoke-on-Trent, Mr. Ashley Myott presiding. The attendance was about 65. Nominations for membership were received on behalf of the following : Collective : Messrs. Wileman & Co., S. Johnson, Ltd., Collingwood Bros., Ltd., S. Hancock & Sons, The Soho Pottery Ltd., The English China Manufacturers Association. Individual : Messrs. F. J. Ridgway, W. James, W. J. Brown, W. P. Moreton, E. D. Green, Houston-Smith, Best, A. Lovatt,

J. H. Thompson, J. R. M. Jeffrey, H. F. Cooper, Parker McKinlay, W. G. Barratt, N. F. Cumming-Smith, J. S. Cartwright. The majority of these new members had been secured by Mr. Ashley Myott. A paper entitled : "The Silica Refractories of South Wales with special reference to the Influence of Texture" by Mr. W. R. R. Jones was communicated by title. Mr. F. S. Worthington gave a few notes on "Tile Making at Sarreguemines," and Mr. H. Barkby gave a paper entitled "A Continuous Kiln in Czecho-Slovakia." A paper entitled "Transmission of Power by Ropes" was given by Mr. P. Kenyon, and Messrs. F. Turner, A. Leese, A. Fielding, T. Simpson and R. M. Jeffrey discussed the subject.

General Meeting held in the Central Science School, Stoke-on-Trent, on Monday, 9th January, 1922. Mr. B. J. Allen presided over an attendance of about 110. The following were nominated for membership : Collective : Messrs. C. Carder & Sons and W. G. Tarrant, Ltd. Individual : Mr. S. Harrison. Mr. T. G. Simpson read a paper by Mr. G. R. Dagnall, entitled "A Description of the Proctor Dryer," and Messrs. F. J. Grocott, J. Burton, J. Williamson and B. J. Allen took part in the discussion on same. Mr. H. Barkby opened a discussion on his paper "Tunnel Kiln in Czecho-Slovakia" which was given at the previous meeting. Sir Arthur Duckham contributed and Messrs. B. J. Allen, W. Lindley, J. H. Marlow, F. J. Grocott and J. Williamson also spoke on the same subject.

General Meeting held in the Central Science School, Stoke-on-Trent, on Monday, 6th February, 1922. About 120 members were present, and Mr. A. G. Richardson presided. Nominations for membership were accepted on behalf of the following :—Collective : Messrs. S. Ford & Co., Ltd., The Brunswick Technical & Pottery School. Individual : Messrs. G. Martin, B. C. Heath, T. E. Wood, R. Wood, M. L. Hartmann, (Ph.D.), The Carborundum Co., C. A. Møller, H. C. Michelsen, J. H. Walton, B. Capper and Miss D. Tyler. A paper was given by Mr. J. Miles on "Spit-Out of Glazes" and Messrs. B. J. Moore, Bernard Moore, G. Price, A. G. Richardson and Dr. Mellor joined with the author in discussing the subject. Mr. F. Davidson gave a lecture on "The Micro-Telescope and Super-Microscope and their Application to Industrial and other Purposes."

General Meeting held on Monday, 6th March, 1922, in the Central Science School, Stoke-on-Trent, Mr. Bernard Moore presiding over an attendance of about 70. The following were proposed for membership : Individual : Mr. D. Cullinan, Mr. G. M. Burnand, Mr. T. P. K. Shirley and Mr. H. H. Thompson. Dr. G. White gave a lecture on "Chemical Porcelain" and questions were raised by Dr. Mellor and Mr. B. Moore. Mr. H. H. Thompson gave a paper entitled "Intensification of Magnets" and demonstrated some of his points with a small model.

General Meeting held at the Central Science School, Stoke-on-Trent, on Monday, 10th April, 1922. About 88 members were

present and Mr. G. Campbell presided. The following were proposed for membership : Individual : Messrs. J. C. Cadman, J. Sneyd, P. E. Cox. Mr. Bernard Moore read a paper on "Spit-Out" of which he was joint author with Dr. Mellor and the following members contributed to the discussion : Messrs. J. Miles, B. J. Moore, F. S. Worthington, C. D. Grimwade, F. Carnall and J. Plant.

Meeting held on Monday, 8th May, 1922, in the Central Science School, Stoke-on-Trent. Mr. W. Lindley presided over a meeting of about 30 members. Officers were elected for the session 1922-23, and a vote of thanks was passed to all who had held office during the session 1921-22. The Councils' Annual Report was read and accepted. The following were proposed for membership : Messrs. C. E. Moore, P. Pemberton, J. T. Webster and G. Jones & Sons.

Proceedings of the Refractory Materials Section of The Ceramic Society.

General Meeting held in the Meeting Hall of the Institution of Mechanical Engineers, Storey's Gate, St. James's Park, London, on Friday, 7th October, 1921. The following papers were read : "The Refractory Materials of the London Basin" by Mr. H. Dewey ; "The Marlow Gas Fired Tunnel Oven" by Mr. J. H. Marlow ; "A New Type of Tunnel Kiln, Oil Fired, with many Novel Features" by Mr. P. J. Woolf ; "The Reversible Thermal Expansion of Silica" by Prof. J. W. Cobb and Mr. H. S. Houldsworth. Dr. A. Granger communicated by title "Aluminothermic Corundum as Refractory Material." A Symposium on Gas Firing followed in which the following took part ; Lt.-Col. C. W. Thomas, Sir Arthur Duckham, Dr. E. W. Smith, Mr. H. M. Ridge, Mr. J. H. Marlow, Mr. H. J. C. Johnston, Dr. M. W. Travers and Mr. P. J. Woolf. In the evening the members and friends dined at the Holborn Restaurant, High Holborn. The meeting was continued on Friday, 7th October, and the morning was devoted to the business of the Society. It was decided that the officers for the coming year should be the same as before, and a small committee was appointed to deal with the whole question of Election of Officers. It was arranged that the Refractory Materials Section should join with the Pottery Section in a visit to Sweden and Denmark. Dr. A. Granger was elected an Honorary Member of the Society. Applications for membership were received from the following : Collective : The Haunchwood Brick & Tile Company and the Crown Gas Stove Co.

Individual: The New York Public Library, Messrs. W. T. Lucas, H. S. Houldsworth, W. H. Bossons, G. B. Brook, C. J. Tidy, C. H. Jones, T. F. E. Rhead (D.Sc.), G. A. G. Thomas. During the afternoon the National Physical Laboratory was inspected and a vote of thanks was passed to the Directors for their kindness in allowing the laboratory to be visited.

The Spring Meeting, 1922 took the form of a visit to Sweden and Denmark. A full description of this trip will be printed in a subsequent part of the Transactions.

The Ceramic Society.

ANNUAL REPORT, 1920-21.

The Council of The Ceramic Society herewith submits its twenty-first Annual Report.

There is nothing very special to report as to the routine working of the Society; the membership roll is:—

Honorary	4
Individual	715
Collective	61
Student	24

We note with pleasure a great increase in the attendance at the Monthly Meetings, the average number present at each meeting being slightly over one hundred.

We mourn the loss by death of Mr. M. L. Williams (Abergavenny); Mr. W. Jackson (Hon. Mem.); Mr. E. Mayer (U.S.A.); and Mr. J. Hollinshead (Stoke-on-Trent). Mr. W. Jackson was the founder of The Ceramic Society, and had been made an Honorary Member a few weeks before his death.

Recently the Council reviewed the question of the publication of the Transactions and it has been decided that publication should be quarterly instead of half-yearly. The arrangement will come into force with the commencement of next session.

The Refractory Materials Section is in a flourishing condition, and a most successful meeting was held at Stoke-on-Trent in May, 1920. Unfortunately the Autumn (1920) Meeting had to be abandoned on account of the Railway strike.

The trip to France and Alsace-Lorraine, arranged to take place next month, promises to be a very successful excursion.

The thanks of the Council are tendered to the Governors of the Central School of Science and Technology for the use of rooms.

F. TURNER,

25th April, 1921. Chairman.

The Ceramic Society.

ANNUAL REPORT, 1921-22.

The Council of the Ceramic Society has pleasure in submitting its 22nd Annual Report. The membership roll now contains 750 names including the following :—

Individual Collective	..	..	..	720
Student	..	..	..	26
Honorary	..	..	..	5

The average attendance at the meetings is nearly double that of years previous to the war, and it approximates to 100, and is an improvement on last year which previously held the record.

Since our last Annual Meeting the Society has completed its 21st year of work and this was celebrated by a dinner at Stoke-on-Trent on Tuesday, 6th December, 1921. Many congratulatory telegrams were received. An index covering the first twenty volumes of the Transactions has now been completed and is being published this week.

The Society had a most interesting trip to France and Alsace in June last year, and obtained much useful information. We shall commence our trip to Sweden and Denmark at the end of this month, and this promises to be one of our most successful excursions. We are assured of a great welcome on the other side.

We acknowledge with many thanks the receipt of a cheque for £100 from the British Pottery Manufacturers' Federation.

The Council desire to thank the Governors of the Central School of Science and Technology for the use of rooms for Metings.

T. A. SIMPSON,

Chairman.

8th of May, 1922.

Our 1921 Oversea Trip.

By H. Townsend.

IT is significant that, up to now, not a single trip has been arranged by our Society in connection with which the social element has not been happily and judiciously balanced by a corresponding measure of trade instruction. Remembering this, it does seem regrettable that for seven long years—from 1914 to 1922—the continuity of this very desirable programme of educative travel had, perforce, to remain broken. But, happily, the war is gradually receding into the background, and aforetime habits are steadily re-asserting themselves. If proof of this were needed, it was surely supplied by our 1921 Excursion, which permitted a fairly strong contingent of our members to spend an enjoyable, if somewhat short spell in the French capital, and to make an instructive and memorable excursion into the heart of Alsace and Lorraine. It will be the aim of the writer to sketch, from the attitude of an interested layman, some of the main outlines of the tour, and to put on record, in as intelligible a form as possible, some of the points which appealed to the members of the tour in general, rather than to the technical mind in particular.

Our 1921 trip to France was arranged on a somewhat more ambitious plan than any previous effort, and it was shared in by a much larger company than at any previous time. Altogether, more than eighty members participated, the list being largely contributed to by members of the Refractory Materials Section. Amongst those taking part in the trip were: Sir Wm. J. Jones, K.B.E., Lt-Col. C. W. Thomas, Dr. J. W. Mellor, Dr. A. Scott, Dr. W. Ludford Freeman, and Messrs. L. Southwood Jones, T. W. Howie, G. B. Chance, J. Holland, R. J. Pickford, C. S. Garland, G. R. Chance, F. W. Higgins, D. Burton, O. F. Glazebrook, H. T. Colclough, C. A. G. Thomas, A. S. W. Odelberg, T. Odelberg, J. C. L. Edwards, W. H. Allen, H. M. Ridge, J. Bagguley, W. B. Cleverly, A. T. Green, C. R. F. Threlfall, S. R. Hind, D. T. Clegg, E. D. Scrivener, H. L. Hartley, C. W. Spiers, S. Hawthorn, G. Blair, R. G. Blair, G. A. Hodson, W. J. Gardner, R. B. Wragg, S. Brooke, W. J. Rees, C. H. Moore, F. H. Brooke, R. G. Howson, A. E. Jones, W. S. Hawley, W. Heaton, P. Hammond, W. Hammond, W. Lindley, W. S. Lindley, W. Bloore, V. G. H. Alcock, J. S. Hutcheson, F. Bridge, A. G. Shaw, J. Heath, W. Nixon, F. H. Heath, A. R. Wood, J. Goodwin, A. Fry, F. T. H. Goodwin, W. Thomason, M. G. Bhagat, Dogar Singh, E. Watkin, F. S. Worthington, W. Hamilton, J. A. Audley, A. Rigby and H. Townsend. The party was also graced by the presence of a select number of ladies, some of whom—wisely,

perhaps—elected to take leave of the main company and to remain in Paris.

The tour may be said to have officially commenced on Friday morning, May 13, as we severally found our way to London, and made a combined start from Victoria by the 11 a.m. boat train on that day. An excellent crossing was experienced by the Dover-Calais route, and it speaks well for the organisation of the travelling arrangements that no untoward circumstance was encountered during the journey from London to Paris beyond the detention for a few hours of one of our members by the authorities at Calais owing to the fact that he had failed to provide himself with a French "visa" to his passport. Happily this recalcitrant member caught us up at Paris the same evening, and was rewarded by a cheer on his arrival at the Hotel Palais d'Orsay, where the bulk of our members were accommodated, the remainder being provided for at the Hotel St. James in the Rue St. Honoré.

On Saturday morning, May 14, a goodly number of us paid a visit to the Foire de Paris—an important industrial exhibition—where we were officially received by the President of the Fair, M. Roger, and presented to the President of the French Republic, M. Alexandre Millerand. An interesting feature of the Fair was a series of important products in refractory fireclays, naturally of prime interest to a considerable section of the party. In the afternoon a joint meeting of the Refractory Materials Section of the Ceramic Society and the French Syndicat des Fabricants de Produits Céramiques was held at the Hotel des Ingénieurs Civils, in the Rue Blanche, in the course of which a special expression of thanks was moved by Sir Wm. Jones, seconded by Mr. S. Brooke and heartily accorded to M. Léon Yeatman for his collaboration on the part of the French ceramists in the arrangements for the present notable tour. Even at this early stage, said Sir William, it was patent to all that the arrangements had been most thoroughly laid, and that an excellent programme was in store.

After the routine business of the meeting had been disposed of, five papers were presented for consideration, four of which, in view of the short time available, had necessarily to be taken as read. These papers covered the following subjects:—"The Plasticity of Clay and its Measurement," by Dr. J. W. Mellor; "Resistance Tests on Refractory Products under Load at Different Temperatures," by M. V. Bodin; "Dinas Bricks of Constant Volume," by M. O. Rebuffat; and "Some of the Difficulties Experienced in Maintaining a Works Pyrometer Installation," by Mr. Robt. S. Whipple, M.I.E.E. A paper by Mr. W. J. Rees, F.I.C., under the title: "Notes on American Practice in Refractories," was summarised by the author and briefly discussed, whereupon the meeting terminated.

The same evening (Saturday, May 14) a memorable banquet was held in the state room of the Hotel Palais d'Orsay, this having

been arranged by the French Syndicate of Ceramists in honour of our visit. Held under the distinguished presidency of M. Lucien Dior, the French Minister of Commerce and Industry, the gathering was composed of many prominent notabilities in the clayware industries of France, and included also distinguished representatives of the French Chamber of Deputies. The banquet hall was a brilliant spectacle, and a faultless repast was provided to the strains of some fascinating music by an accomplished orchestra under the direction of M. Hector Guillet, of Concerts Colonne fame.

It fell to M. Guérineau, the retiring president of the French Ceramic Syndicate, to propose two loyal toasts (1) to H.M. King George V., "Roi de la Grande Bretagne et Empereur des Indes," and (2) to the esteemed president of the French Republic, M. Alexandre Millerand. In a subsequent speech M. Guérineau rejoiced, first of all, in the presence in France of a distinguished company of manufacturers of English ceramic products, for this, he thought, showed that the French and the English "industriels" still maintained a spirit of real confidence in their mutual dealings, as well as a brotherly good-fellowship in their receptions. He recalled that, in 1902, on the occasion of a fête which united the English and the French manufacturers of ceramic products, the "entente cordiale" was, in that very room, cemented. He had, therefore, very great pleasure at the present time in welcoming a company of English friends to France, and particularly to that very room, in which the words "entente cordiale "were first crystallised, especially as it had now been proved that the "entente cordiale" would save the world and civilisation. He did not wish to enter into politics, but he desired just to say this: that the hearts of all the French ceramists were beating that day with the hearts of their English contemporaries just as the hearts of the French soldiers beat in tune with those of the English soldiers throughout the war. Whatever might be the trend of the discussions between their respective Governments, there was not—and never could be—any real difference between the sentiments of the two peoples, and whenever they met one another they were sure to understand each other, and to be of help to one another, as well as to their respective Governments, by being always united in perfect friendship.

Proceeding, M. Guérineau said that the ceramic industry, which was a calling of exceedingly complex ramifications, was unfortunately so scattered that it did not create, at first sight, a fair impression of its magnitude; but, without speaking ill of metallurgy, mechanical engineering, the chemical industries, or the manufacture of textiles, all of which represented a source of considerable business, it was true to say that the ceramic industry contributed very largely to the economic life of France. The brick industry alone accounted for a total production of close upon

twelve thousand million bricks per annum in terra-cotta, without taking into consideration silica-lime and other artificial types of bricks. In addition, there were numerous factories manufacturing drain-pipes, and the output of the important mechanical tileries, which were grouped in districts, accounted for a production of close upon 600 million pieces annually. The factories for the production of refractories had, in 1914, a capacity for turning out 500,000 tons per annum, and employed 3,500 workmen. Since then, however, several factories had been enlarged; others had been newly constructed—unhappily without taking into account the question as to whether the demand justified the increased production, which was now nearly 700,000 tons per annum.

The manufacturers of *objets en grès* (stoneware) for the chemical industry knew how to adapt themselves very speedily to the problem of national defence; happily, too, the manufacturers of heavier types of clayware knew equally well how to respond to all war-time demands. The manufacturers of enamelled tiles for the ornamentation of walls, and ornamental earthenware manufacturers, were not particularly numerous in France, but they were certainly very important, and they amply sufficed for the needs of the country. It was worth remembering that for a long time the porcelains of Berry and of Limousine provided for the needs of the whole world, and although since then foreign knowledge of ceramics had powerfully manifested itself, the porcelain of Limoges would still remain, as of old, the mistress of the race, both from the point of view of the finish of the work and of the tasteful decoration that was entailed in it.

The electrical porcelain of France had made considerable strides, and without doubt could fulfil the needs both of the great metropolis and the French provinces and colonies. The pipe factories of France produced annually about 100,000 tons, and could easily satisfy all the demands made upon them, even if the big towns were to adopt, as was desirable, a complete drainage system. The manufacture of sanitary ware was likewise indicating important developments in France. On the contrary, the production of decorative ceramic wares had subsided a little. Simultaneously, the production of ceramic heating appliances—chimneys, stoves, and such-like—had appreciated, and there was a tendency on the part of the public to demand its employment in preference to marble.

M. Guérineau proceeded to speak of the founding of the Institut de Céramique, which, he ventured to think, would considerably assist in the future development of the industry.

M. Léon Yeatman, who kindly translated the foregoing speech for the benefit of the English guests, added on his own behalf that he would always remember the hearty hospitality which he and his colleagues received at the hands of the Ceramic Society on the occasion of his visit to England a year ago. He

remembered with delight the numerous charming spots which they visited in England. He remembered particularly the garden county of Kent, as well as Stourbridge and the "Five Towns." He recalled with something akin to sentiment, a delightful lunch and a charming tea which were provided for them at the North Stafford Hotel, Stoke. He remembered, too, with a feeling almost bordering upon envy, a wonderfully well-equipped laboratory possessed by Dr. Mellor at Stoke. It might, perhaps, interest some of the gentlemen present to know that since that visit a year ago, the French ceramists had endeavoured to create a laboratory on somewhat similar lines, though on a much smaller scale. They only hoped that it would eventually grow into as fine an institution as the one at Stoke-on-Trent of which Dr. Mellor was the distinguished head.

Sir Wm. J. Jones, K.B.E., who next spoke, threatened to embarrass the English reporter by opening out his speech also in French. He said: "*Monsieur le Ministre, monsieur le Président, messieurs les membres de la Société céramique de France, je ne parle malheureusement pas français, ou j'aurais été heureux de pouvoir vous offrir en votre langue, de ma part et de celle de mes collègues, les remerciements les plus sincères pour cette splendide hospitalité comme les français savent si bien le faire.*" Lapsing into English, Sir William said that that was the longest speech he had yet delivered in the French language; indeed, it was his first. "Permit me," he continued, "on behalf of the English Ceramic Society, to express to you our heartfelt gratitude for all the kindness which you have shown, and are showing, to us on the occasion of this visit to your beautiful country. I am quite sure that that splendid spirit of comradeship which the recent devastating war has cemented between our country and yours will be strengthened by the visit of our Society, and by any other meetings such as the one we are now holding. The Ceramic Society has this year attained its majority, so that we come before you having now reached full age, and, I hope, the age of discretion. I think the very fact that we have celebrated that coming of age by coming to Paris does, indeed, indicate a certain amount of discretion. Had it not been for the industrial troubles in which we are now involved in England, I am quite sure that the number of representatives of our Society at this particular gathering would have been much greater, and your hospitality would have been stretched to its utmost limits.

"The objects of our Society differ, I understand, in some respects from those of your Society, and I may briefly sum them up in this way: The Ceramic Society is essentially a quasi-scientific society, which has for its objects, first and foremost, the improvement of all that pertains to the ceramic industry. We provide a common meeting ground for manufacturers and users of refractories to discuss and overcome the difficulties which the one en-

counters in the process of manufacture, and the other discovers in the application of the manufactured goods. We contribute to the knowledge of refractories by considering papers by eminent men in the refractory art, and by holding discussions on these papers. It is fitting that I should say here that our Society is greatly indebted to several distinguished Frenchmen who have from time to time contributed papers to its Proceedings. Amongst others, we have as members of our Society the distinguished Professor Le Chatelier, and we have had papers also from Messieurs Bigot, Granger and others. We also endeavour to further the interests of the ceramic industry by arranging excursions from time to time, and viewing various works, both at home and abroad. Our Society, like many others of a kindred nature, is always poor. It is perennially poor. We have only a very small subscription, sufficient to pay for the printing of the Proceedings and the passage of correspondence.

"We have two urgent needs in the Ceramic Society. The one is the need of further research work, and the other is the need for a closer study of the question of fuel economy. We have, as you may know, instituted a British Refractories Research Association, which is supported by funds in a measure provided by the British Government, and part provided by the manufacturers of refractories in our country, but I am sorry to say that the Association does not receive that enthusiastic support that is sometimes displayed towards other objects, perhaps less worthy. What I feel is, that manufacturers are rather too prone to regard any expenditure on research as 'too long a shot' to be remunerative. I feel that what they need to be convinced about—and I should be very glad if you could assist in any way in this regard—is that any money spent on research is the best investment possible. With regard to the question of the economy of fuel, I think that for us in England the days of cheap fuel are gone, probably never to return. When one considers that the consumption of fuel in our country for the production of refractories amounts to something like £3,000,000 a year, it is obvious that there is scope for great economy in that particular direction. What our industry requires is cheap fuel and cheaper labour. However, I am not expected to go fully into such questions as these to-night, for I understand that all matters political are taboo. I would like to say that from the most interesting exhibit which I had the pleasure of visiting this morning, I am inclined to think that the French ceramic industry—at all events the refractory materials industry—is a little ahead of us. I think it shows that, in your case, scientific application is more general, that you pay more heed to the special requirements of the materials which you manufacture, and that you adapt your manufacture by blending your clays in a way which, as I say, is more scientific. May I be permitted once more, on behalf of the Ceramic Society, to express to you our heartfelt thanks for your great kindness to

us, and also to express the hope that you will pay us a return visit in the near future."

M. Dior, Minister of Commerce and Industry, in a vigorous speech—naturally delivered in the French tongue—recalled that in the chemical industry, to which he belonged, one often had occasion to appeal to the pottery industry. The chemical industry had, indeed, great need of the pottery industry. For 30 years he had been able to appreciate—perhaps better than most people—the value of the co-operation which the French potters had extended to those who sought their help. He had also been pleased to witness the numerous successes which the pottery industry had recorded. By their conspicuous war services the French potters had earned the gratitude of the entire French nation. During the war the country was faced with innumerable needs—difficult and new. In connection with the manufacture of explosives, it was not merely necessary for the potters to struggle against temperature, but against corrodibility. Staunchly, however, had the potters worked and won through. They had been good workers during the war, and he was happy to add that they continued to be good workers in times of peace. "I salute," continued the Minister, "our English friends. Their presence here is an index that our dealings are amicable, that we are not only allies, but friends." He raised his glass to the union which united them to their English friends; to the union which made for unity amongst the French manufacturers, who, although competitors, still knew how to remain friends; to the union which endeared each one of them to the interior of his own house, where they all knew that union was strength; and finally, to the union which united France and humanity.

Towards the close of the banquet M. Houbé, the oldest of the Syndicate's vice-presidents, presented to M. Ch. Guérineau, as a mark of the esteem of his colleagues on the occasion of his retirement from the presidency of the French Ceramic Syndicate, a marble statuette, mounted on a mahogany plinth, the work of the sculptor Fernand Dubois. In the course of the presentation it was explained that the subscription which was opened for the purpose reached a high figure, and there was a considerable surplus. This surplus had since been augmented by a personal donation from M. Guérineau, and it had been decided that it should be utilised as an endowment fund with which to provide comforts for the aged workers of the pottery industry. M. Houbé having embraced M. Guérineau in the approved French fashion, the latter, who was visibly moved, uttered a few words in acknowledgment of the gift, after which "Vive le President" was called by M. Léon Yeatman, and was responded to vociferously by both the French and English contingents.

Thus concluded a gathering which was afterwards referred to by a North Staffordshire stalwart as a real epoch in Anglo-French

ceramic history.

On Sunday, May 15, the whole of the day was occupied in a trip by motor-coach to Malmaison and Versailles. On the outward journey in the morning a halt was made at the Etoile, where the Society paid a fitting tribute at the tomb of the unknown French warrior. A handsome wreath, which had been subscribed to by every individual member of the party, was placed on the vault by Mrs. J. W. Mellor, the company standing at the grave for some moments with uncovered heads and in silence.

Of the historic features both of Malmaison and Versailles, much might be written had one the time and space available. As it is, however, one must pass over this particular outing rather summarily, refraining from mentioning anything either of Napoleon (who seems to be particularly popular in Parisian circles just at present, probably on account of the recent centenary celebrations) or of the last of the French monarchs, whose extravagance led up to the Revolution and ultimate republicanism. Similarly, a number of photographs bearing on the social side of this very enjoyable outing must be relegated to the domestic portfolio, to call up happy memories, it may be, years hence.

On Monday, May 16, a somewhat serious programme of travel was begun, which was prefaced by a 6 o'clock breakfast. By 7-35 a.m. a happy party, consisting of about seventy Englishmen and thirty or forty Frenchmen, practically all of whom were more or less directly interested in various departments of the clay-working industries, met at the Gare de l'Est, boarded the Paris-Verdun-Metz express, and were early en route for Verdun, where it had been arranged that a few hours during the afternoon should be spent. The run through the valley of the Marne, passing through Château-Thierry, Épernay and Chalons, was full of interest, as, for some hundreds of miles, there were concrete evidences of the oscillating fortunes of the contending armies, and every member of the party was able to get a better idea of the extent and the grimness of the struggle which the years from 1914-1918 witnessed.

It was not to be wondered at that a considerable number of the younger members of the party had seen war service in France, but generally, of course, on that particular front north of Paris. During those memorable, trying days of Ypres, Arras, Cambrai and the Somme one was often inclined to wonder how our French allies were faring in the wine country. One heard from time to time a good deal about the Marne, and particularly of Verdun, and one was constrained to wonder sometimes whether any section of the battle front was quite so strenuous as one's own. A trip across the French lines is quite sufficient to assure one that the hammer blows of the enemy were well diffused along the entire front, and that on few sectors of it did the Allies have what the English "Tommy" would call a "cushy" time. It was not, however, unti-

the party detrained at Verdun, motored through the town, called at the Citadel, passed through its subterranean passages, and thence on to the battlefields adjacent, that a really intelligent concept was formed of the ravages of the war, and the losses that it entailed in life and material.

Lunch was partaken on the train during the journey between Paris and Verdun, and on arrival at Verdun station motor coaches were found in readiness to convey the party to the famous Bayonet Trench, and the wilderness of a country in the neighbourhood thereof. One makes bold to say that the half-day that the party spent in the environs of Fort Douaumont, Fort Vaux, Thiaumont, and the quarries of Haudromont, will never be forgotten. The Belgian front is impressive enough in all conscience, but the memory of Verdun—the cemetery of a million soldiers, for the most part interred *inconnu*—will remain with all who shared in the trip as a gruesome lesson of the havoc that can be wrought by modern warfare.

Leaving Verdun in the late afternoon, we continued our motor trip as far as the village of Etain, on the main road to Metz, and spent some time here in viewing the local ruins, several of us making a special point of visiting the partly-demolished church. Owing to the exigencies of the motor coach service, a division of the party was then considered necessary, about half of us journeying onwards to Metz by train, the other half continuing the trip by road. On arrival at Metz, accommodation was found to have been reserved at the Hotels de Metz and d'Angleterre.

It may be mentioned here in a casual way that the provision at the Metz hotels appears to fall far short of what might be expected from a town of such size and importance. Somehow, Metz does not seem to have accommodated itself quite so readily to its changed conditions as have some of the neighbouring pre-German (now French) towns; its assimilation to new conditions and administration appears to be coming more slowly and somewhat less willingly than in the case of Strasbourg, which was later visited. But this is merely a personal impression formed as the result of a two-days' stay in the town. It is perhaps, hardly to be expected that after nearly fifty years of German rule every single inhabitant can be entirely French in his sympathies, and whilst one saw no evidences of ostensible hostility, one did at least meet with instances, especially from the hotel garçons, where anything in the nature of real cordiality towards allied visitors was visibly wanting.

On Tuesday morning, May 17, another 6 a.m. breakfast was partaken of, and by 7 o'clock both the French and English contingents of the party were aboard a special train and en route to Mettlach, with a view to visiting one of the principal pottery works of the well-known German firm of Villeroy & Boch, two of whose factories are now found within the militarily occupied zone under

the terms of the Armistice and the Treaty of Versailles. Mettlach was reached before 9 o'clock, and a short walk through the village brought the visitors to the front gates of the works*, situated on the bank of the river Saar, a tributary of the Moselle, a lovely river which runs a tortuous course before emptying its waters into the Rhine. The Saar itself is a captivating river, and the valley through which it runs possesses the charm of almost indescribable picturesqueness. Running every now and then between steep, densely-wooded heights—one is here on the edge of the Black Forest—the river takes a wide turn, skirts the ancient castle of Montclair, and sweeps down upon Mettlach, the site of a sixth-century Benedictine monastery, in the very buildings of which the present Mettlach pottery was founded. One is forcibly reminded of this as one enters the works by the front gates, for, carved over the entrance, one discovers the Benedictine motto, "Ecce Labora." Thus, on the beautiful wooded slopes which scale down from Montclair, a view of which some members of the party walked some distance along the river bank to take in at its best, are to be found, not merely the ruins of a historic abbey, but a colony of some thousands of potters, producing a grade of earthenware which, although it may not compete seriously with our English productions—in the home markets of Great Britain at any rate—has made itself something of a power in mid-Europe.

The monastery buildings, which run parallel to the river, are surrounded on three sides by a very picturesque park, which contains a wonderful Xth-century, ivy-covered tower (erected by the Benedictine monks from a model of Aix-la-Chapelle Cathedral), several charming lakes, well-kept flower-beds and shady trees. In this park, through which runs a branch of the Prussian State railways, large numbers of the surrounding population are apparently in the habit of picnicing, few restrictions being imposed. We were informed that the tower, already referred to, was repaired in 1851 by Privy Councillor Eugene von Boch, who himself superintended its renovation, and it is interesting to note that this particular tower forms part of an impressed trade mark in the clay to be found on all the art-ware productions in stoneware which the Mettlach factory produces, and without which the genuineness of the piece may seriously be questioned. As one passes through the main portico of the factory buildings, one is struck by the magnificent scale upon which the buildings were erected. A handsome, lofty staircase, possessing an exquisitely sculptured ceiling, suggests that the old monks were, at all events, men of affluence. It is, of course, only natural that the monastery was plundered and well-nigh irreparably damaged during the French Revolution. The monks were driven out, never to return, and the property, which was seized by the Republican State, was sold, ultimately falling into the possession of Mr. Jean François

* Since destroyed by fire (Aug. 11-12, 1921).

Boch. This was over a hundred years ago, and Mettlach was then a small fishing village, comprising not more than twenty families. The future prosperity of Mettlach was, however, sealed when Mr. Boch decided to convert the ruined buildings into a pottery works. The work of manufacturing was begun in a humble way, but the story of its progress can best be imagined by the statement that on the outbreak of the war in 1914 some 3,000 pottery workers were finding employment in the village. (Only about half that number are so employed to-day).

It is claimed by the Villeroy & Boch firm that the story of the trials of Palissy and Wedgwood is only another way of expressing the early trials of the founder of the Mettlach works, for one of the governmental conditions imposed upon Mr. Boch when he commenced to manufacture pottery at Mettlach was that he must use hard coal in the firing of his wares. All the other ceramists of Europe were at that time using wood. By dint of perseverance he succeeded with coal-fired kilns, utilising the coal in which the basin of the river Saar abounds, and it was in consequence of these successes that other European potters later turned to coal as a fuel. In the course of his researches in this direction Mr. Boch also found time to perfect a system of water-power for turning the potters' lathes which, previously, had invariably been turned by the feet. (It is interesting to note that the old method of foot-drive is still pursued not a hundred miles from Mettlach, and the writer of the present article was fortunate in securing an actual photograph taken during the trip.) Amongst other innovations which are attributed to the founder of the Mettlach pottery is the provision of the first plant for the underglaze printing of earthenware on a mass-production scale by means of transfers from copper plate engravings. That Mr. Boch was a man of energy and enterprise can easily be read into this brief historic sketch of the early development of the Mettlach factory.

An added zest was given to the operations of the Mettlach pottery in 1841, when an amalgamation was formed with two other factories, one of these being situated at Wallerfangen, near Saarlouis, operated by Mr. Nicholas Villeroy, and the other at Septfontaines, near Luxembourg, established by Mr. Pierre Joseph Boch, the father of the founder of the Mettlach works. An interchange of experiences, and the consequent installation of new and additional plant, led to rapid advancement, and the firm of Villeroy & Boch soon came to be recognised as the premier pottery-producing house of Germany. The earlier productions of Mettlach, which had lacked variety, were supplemented by other types of wares; a more aesthetic type of art was sought for, and a higher standard of quality cultivated throughout. The firm's output increased enormously; agencies were established in all the principal cities of Germany, as well as in a good many places abroad, and the firm's trade mark became popular particularly throughout

the whole of Central Europe. Amongst other things, the manufacture of stoneware was begun, in a good deal of which relief modelling was a feature. Later, in place of bas reliefs, inlaid ornamentations were resorted to, these being reminiscent of cloisonné enamel work. Originally this type of ware was uncommercially high in price, but a more popular rendering of it was eventually realised, samples of which the writer has from time to time seen in numerous retail establishments in the course of his travels, and it is undoubtedly to this particular type of ware that Villeroy & Boch owe a good deal of their present reputation.

In the Mettlach museum we were able to see innumerable specimens of the firm's stoneware productions in both old and modern styles, all of which were admittedly of exceptional interest. Some of the patterns were sternly geometrical in design, others quite pictorial. The interstices of some of the patterns appeared to have been filled in singly by different coloured Barbotine slips. One pattern, which was of exceptional interest, assumed a pâte-sur-pâte treatment in Wedgwood style. Other patterns suggested the use of the stencil and a subsequent washing-in. There was certainly no lack of variety in the renderings of stoneware design to be viewed in the firm's showroom.

After inspecting Villeroy & Boch's creations in stoneware, we passed through to another room, in which was displayed a comprehensive selection of domestic earthenware. There were some very attractive designs in toiletware, and although these were mostly on the heavier and rather solid-looking shapes, suggestive of Homburg rather than Mayfair, there is no denying that they were calculated to appeal specially to their own particular markets. The underglaze prints, especially in border styles, showed up to great effect; in particular, the pinks and the blues seemed to be full of life and tone. Wide, black-and-gold borders in toiletware were a topical feature of the display, and another line in which the writer was interested was a range of acid gold border effects in toiletware, secured through the agency of liquid gold. Household store jars, which have always been a feature of the productions of the house, were also seen in many attractive styles of simple ornamentation.

Having inspected the showroom—all too hurriedly, as the time allotted in the programme to Mettlach was definitely limited—a tour was now made of the works. It will be quite impossible, within the limits of an article such as the present, to describe in detail all that one was able to see. At most it is only practicable to pick out here and there a few of the principal points of interest. Again, it must be remembered that our party was so large that it was found necessary for us to subdivide into sections, and not all the sections were able to see precisely the same features.

Beginning with the biscuit warehouse, the section of the party

to which the writer was attached was impressed principally with the runway installations. A narrow-gauge railway was seen to run right through the building, and at every junction of gangways was situated a little turntable on which the trucks could be veered off at will to right or left. This was a feature not exclusive to the biscuit warehouse, but common to the majority of the work-shops, and, if we remember rightly, it was one of the points in factory organisation which specially impressed that party of North Staffordshire manufacturers who, in 1918, paid a visit to a number of the factories in the occupied zone. With the exception of this feature, there appeared to be nothing really new to be seen in the way of biscuit placing. A hurried tour was made through some of the pressing and casting shops, including the making of sanitary ware. In connection with the making of earthenware closet pans, one noticed that the side lugs and the inlet horn were being cast separately. The saggars were of a very nice uniform colour, and they appeared to be rather thinner in construction than those generally encountered in Staffordshire. The saggar wads were seen being made in a pug specially designed for the purpose. Inquiries made of the guide elicited the information that the saggars have not a great deal of life; it was affirmed that usually they can be relied upon to last for not more than four or five firings. It was recognised by the firm themselves, said the guide, that they have not yet given as much attention as requires to be given to the blending of the saggar marls.

The drying stoves at the works of Villeroy & Boch proved rather interesting. They were provided with a series of hinged metal doors which, on being lifted upwards, only gave access to a couple of stillages at once. These hinged doors ensured that the stove was always closed, except when it was necessary to lift them up to insert ware or to remove it, thus providing against any loss of heat through failure to close the doors after use.

The ovens, or at least those of them which were of the old circular type, were seen to be arranged in groups—four biscuit and four glost—and they were well served in regard to transport facilities. It was also noticed that in various portions of the works the floors, in order to ensure in some cases the maximum of cleanliness and in others the maximum life, were laid with "seconds" tiles, which were sometimes laid in the orthodox fashion, and sometimes placed endwise as as to be highly resistant to wear and tear.

In the glazing of the ware it was noticed that a circular mangle is used by the dipper, and a circular tunnel dryer by the taker-off. Girls were to be seen engaged in the actual dipping process, using an iron clip with which to hold the plate or dish, and giving this seven or eight turns in the dipping tub. In the glazing of large pieces of sanitary ware it was observed that reglazing or patching is performed sometimes by means of an aerograph and sometimes

by brushing, the repaired portion of the glost piece being distinguished by the use of a flesh-coloured vegetable dye. At the glazing tub any glaze that is spilt in the process falls into a trough below, and is collected for special treatment.

In the decorating shops, through which the whole of us passed in turn, it was apparent that stencilling is a method that is largely employed. In some of the patterns quite a range of different stencils is used. In a fruit design, for instance, a stencil is first employed for the fruit, and the colour blown on ; a supplementary stencil is afterwards used for the leafage, the colours being blown on in the same way ; and in the whole of this applied treatment there is taken into account a relief in the mould which, of itself, gives part of the decoration. The use of lithography is also generously indulged in at the Mettlach works, many patterns being underglaze. The firm makes all its own lithographs, in which there appears to be a very good palette of colours. It was noticeable that, in the case of those decorating shops where co-operation is necessary between one set of workers and another, a mechanical conveyor is always provided in the form of an endless chain or a conveyor belt. This is a point which cannot be too strongly urged. Wherever communication between one department and another has been found necessary it has always been arranged for mechanically.

One of the most interesting portions of the Mettlach works was, perhaps, that connected with their tunnel ovens, which are really a modification of an original Faugeron. For fifteen years the firm of Villeroy & Boch have had the advantage of continuous firing of this form. Their first oven was apparently a true Faugeron; their second, which has been installed more than ten years, is seemingly a modified Faugeron. These two ovens, which run side by side, are approximately 210 ft. in length ; they are fired with producer gas, and the flame plays directly upon the saggars. About twenty-four hours, we understood, are occupied in the firing, the trucks being drawn at the rate of one every half-hour. An alarm bell rings every time a truck is due, and the whole arrangement seems to be simple and fairly automatic. Asked whether they experienced any real trouble with tunnel firing, our guide replied that only once had they encountered any real difficulty viz. :—during the war, owing to the depletion of their staff and the quality of their materials. Incidentally he remarked that over a hundred of their operatives had lost their lives in the war, and the call upon the male staff of the factory during the conflict was so insistent that the whole of the clerical work had to be carried on for some years by six small girls.

A visit to the saggar-making department of the works was more than ordinarily interesting. It was quite apparent that, although the firm may not yet have solved the saggar question, which is one of the most important of all questions to the modern and future pottery manufacturer, they have at least paid special

attention to the *making* of their saggars. A special saggar house was observed to be fitted up on something like an ordered plan. At the top of the building the grog is crushed in a Blake crusher, and an arrangement is provided by means of which any material that is too coarse goes back automatically to the crusher. The grading of the materials is performed automatically, the finest being taken away as it is delivered. The saggar clay is crushed on edge runners, and is automatically mixed with the grog ; it is also automatically conveyed to the pug-mill in the dry state. Water is added in the pug ; not before. The prepared marl, which is neither allowed to weather nor is trodden, is taken to the saggar maker, who deals with it first of all on a hydraulic marl press, which presses out a lining. This lining is transferred to a cast-iron drum, sized with marl. The drum is placed on a plaster bat and taken to a jolly, the profile used being of hard wood ; not of iron. Three jolleys are provided, one for each man, and from information which the writer was able to elicit, these arrangements are responsible for turning out 260 saggars in the course of an eight-hour shift. We noticed that one of the jolleys was engaged in the making of round saggars, whilst another, on the lines of an oval dish machine, makes the oval saggars. After being jollied in this manner the saggars are taken away by means of a carrier to another room, where they receive the finishing-off touches. Careful attention is clearly paid to sound finish. The writer had a talk with a British manufacturer in regard to this plant, and sought his views as to its efficacy. He was of the opinion, however, that considering the capital outlay involved in the provision of such a plant, and the fact that five men in all are engaged in its operation—two at the pipe machine pressing out the saggar sides, one at the jolley, one fettling, and one in the hothouse—there was not very much ultimate economy in it. However, it certainly appealed to the writer as an ingenious arrangement, one which showed a feeling towards systematic working and standardisation of conditions, and one which was worthy on this account of some consideration by all who are interested in saggar production.

There were many other points in connection with the Mettlach works about which, if one had the time, one could write with pleasure, and possibly with some measure of profit, for, after all, there is nothing like writing to impress on the memory what one has seen in the course of one's travels. Time and space forbid this, however ; our account of the visit to this particular factory must be brought to a conclusion, for there are others about which we have to report. It is hardly necessary, in summarising, to state that the main features which impressed the visitors to Mettlach were (1) the ideal situation of the factory, and (2) the very systematic layout of the newer portions of the works, particularly in regard to the arrangements made with a view to guarding against unnecessary expenditure of human energy.

There is one other important feature of the Mettlach factory administration which cannot be passed over without a special mention and this has reference to the provisions which have been made for the welfare of the workers. Mettlach being a village, many of the operatives naturally reside at some distance from the place of their work. To meet the needs of such workers, a special train, composed of the firm's own coaches, daily brings them backwards and forwards between home and factory. In the case of those who live nearer the factory—that is to say, in the suburbs of Mettlach—specially heated waggons call at the homes of the workers, and bring to the factory at mid-day their hot meals, prepared by their own families in their own homes. For a number of young women workers who live at a distance, and who find it impossible to get home except at the week-end, accommodation is provided during the working week at a local convent. Before the war, accommodation was provided in several local refectories and dormitories for a number of both male and female workers, at a charge for board and lodging in the region of 7d. per day. The war, has, of course, altered the scale of charges, but the principle remains. Art instruction is provided for ambitious juniors, and those who avail themselves of the instruction thus provided are reimbursed for any time lost at the factory in consequence. On one of the mountain sides stands a large pavilion and restaurant, complete with summer garden and winter concert hall, for the special use of the employees, all sorts of recreative sports being provided. In the Saar, bathing *au naturel* can be indulged in through the medium of the firm's own swimming bath, in charge of a capable swimming instructor ; and at both the Mettlach and Merzig factories of the firm there have been provided hot baths and shower baths, the use of which is obligatory upon the lead workers, and is enjoined but not enforced in the case of the remaining workers. Medals are given by the firm for long service ; marriage gifts to both male and female operatives ; money grants at 3 per cent. interest to employees wishing to build their own houses ; pensions, based on length of service, to the aged and incapacitated ; gratuities to the widows of workers ; and endowments to their bereaved children. We have recently begun to talk about welfare work in England, but in this respect we have surely something to learn from the Continent, and we must not make the mistake of discounting the lesson because of the source from which it comes.

On completing the tour of the Mettlach works, the principals kindly entertained the whole company to light refreshments in one of the upper rooms of the old Abbey—a service that was warmly appreciated. A run round any large factory is usually productive of an appetite, and full justice was done to some really perfect sandwiches, which were kept good company by the yield of an apparently well-stocked cellar of Moselle wines.

At twelve noon, the same day, our special train, which was

waiting in a siding at Mettlach station, was boarded, and was soon under steam for Merzig, where another unit of the Villeroy & Boch chain of factories (there are eight or nine altogether) is situated. At this particular works the firm manufactures quite a variety of commodities, including terra-cotta statuary, vases, architectural ornaments, mosaic tiles, stoneware pipes, and certain of the heavier and coarser clay wares in refractories. There were several factors which tended to make this particular visit somewhat less entertaining than the inspection of the previous works. One of these factors was undoubtedly that the majority of the members of the party were feeling more or less tired. Already the effects of enthusiastic sight-seeing, long railway journeys, and five o'clock risings were beginning to reveal themselves symptomatically, and the result was that a somewhat less active interest was displayed towards details. One of the first impressions formed of this particular factory was, perhaps, its extremely healthy location. It was found to be situated in some fine, open country, bordered by wooded hills and cornfields.

The Merzig factory, on the same lines as that at Mettlach, is splendidly equipped with interior railway and transport facilities, and another point which one is quick to notice is that the factory has been located right on the side of the State railway, thus obviating anything in the nature of cartage either of the raw materials or the finished goods. A point that was distinctly noticeable in the case of all the factories that were visited during the trip was the careful manner in which the buildings have been erected either by the side of a navigable waterway or alongside a railway. Circumstances have been rather more favourable to the Continental manufacturers in this respect; for two reasons: (1) the factories are in many cases of more recent origin, and (2) there has been no limitation in the matter of floor space. In the case of the Merzig factory, ground space has been used prodigally; the factory is entirely single story, having been built in a series of bays, each of which is served by a miniature railway, and the main gangways fed with a broad gauge line along which full-sized railway wagons can pass uninterruptedly from end to end of the factory. All this, of course, bespeaks economy in handling and ultimately cheaper production.

Not very many features of the Merzig factory are indelibly impressed upon the writer's mind. One of them—the chief, perhaps—was a splendidly-equipped engine house, which, one observed, was fitted with a duplicate set of engines, so as to guard effectually against any possibility of stoppage of work through breakdowns. In wandering through the works it was clearly apparent that the output of the factory must be something enormous, for the round-shaped ovens, which were all numbered, were observed at one end of the works to be in the region of the seventy

numerals, and besides these there were several continuous ovens on the chamber gas-fired principle.

From the entrance of the works to the engine-house must have been a distance of fully, or even more than, half a mile, and in the course of this walk opportunity was provided of noticing how the clay is brought down from the mill to the various parts of the pottery in which it is required in private railway wagons by means of the firm's own locomotives. Too much insistence cannot be placed upon the economies which must arise from these internal arrangements for transportation, both in big and small matters. In not a single case were men seen to be employed in carrying about either materials or finished goods. This was always done by some form of railway or other type of conveyor.

It was obvious from the large stocks of sanitary pipes that were resting in the region of the despatch department that at the Merzig works this is an important branch of the firm's activities.

At the close of the tour of the Merzig works we made our way to the Hotel Triercher Hof, in the heart of the town, where we were occupied by a long-drawn-out luncheon involving practically the remainder of the afternoon. Our special train was again boarded at 5 p.m., and the return journey continued to Metz, where the evening was spent in the prosecution of individual and sundry diversions.

Metz, the capital of Lorraine, where we spent two evenings, was interesting, but it was not until after Metz was left behind that the most informative part of the trip, from some points of view, really began. From the viewpoint of the manufacturer of domestic pottery, nothing could have been more interesting and instructive than the visit which was paid on the morning of Wednesday, May 18, to Sarreguemines. Again a special train had been chartered for the day, and leaving Metz at 7-15 a.m., a picturesque run of one and a half hours was made by way of Remilly and Bening, Sarreguemines being reached *de bonne heure*. Sarreguemines has long been a household word on the Continent so far as pottery is concerned, and we were naturally all fully expecting to see, at the Usines des faienceries de Sarreguemines, owned by Messrs Utzschneider & Jaunez, something really worth writing home about. The statement that we were not disappointed in this can be ventured right away. The visit proved to be one that is worthy of being long remembered, for it certainly had the effect of opening the eyes of a good many of those who were making their first inspection of Continental factories, conveying a better idea of the growing inportance of the pottery industry in these parts, and suggesting the advisability of not regarding too cheaply the possibility of competition from this particular quarter.

On arriving at Sarreguemines, we were met on arrival at the works by one of the directors of the company, M. Windergast, who personally acted as guide to one of the sections into which the

company had necessarily to be divided during the tour of the works. It was from this gentleman that the writer learned a good deal of the historic side of the factory, and some of the facts appear to be well worth recounting before making any references to modern practices. The first fact to remember is that it is probably 140 years since pottery was first made at Sarreguemines. An official piece of ware, dated December 28, 1790, bearing the name of the founder of the works, Mr. Nicolas-Henri Jacobi, is considered to be proof of its existence at this period. In 1793 the control of the factory, which at that time produced only an indifferent brand of ware made from white pipe clay, was entrusted by the proprietors, Jacobi & Fabry of Strasbourg, to François-Paul Utzchneider, who, thanks to his business instinct and artistic taste, was responsible for the first trials of high-grade earthenware, and ultimately established the international reputation of Sarreguemines as a pottery-producing town. It is interesting to note that Mr. Utzschneider, like so many other foreigners imbued with progressive ideas, had for some time studied the manufacture of pottery in England, but was drawn to France by the critical events which were occurring there at the end of the eighteenth century. After fighting for France in two campaigns, he was found by Mr. Fabry in hiding at the home of a French soldier in the environs of Besançon, and, as the Jacobi family had recently retired from the Sarreguemines concern, Mr. Utzschneider was taken into partnership along with Mr. Fabry, the name of the firm now becoming Fabry & Utzschneider.

About the year 1800 Paul Utzschneider carried off for his productions the gold medal of honour, and for the first time the name of "Sarreguemines" became popularly heard of. From this time onwards the opportunity of showing the products of the firm was embraced at every new exhibition, and one success after another was recorded, indicating the rapid developments which were taking place at Sarreguemines under Mr. Utzschneider's administration. It would be impossible to mention the whole of the firm's successes in the early years of the nineteenth century, but one or two items seem worthy of special citation. In 1801 Mr. Utzschneider gained a gold medal for his first trials of figured stoneware on the lines of the Wedgwood ware which he had seen being manufactured in England. This ware was considered to be worthy of the name "French Wedgwood," to such a fine degree had Mr. Utzschneider imitated the famous English potter. Amongst other carefully preserved examples of the early productions of the firm are to be found vases and candelabras imitating porphyry and granite. It is recorded that, upon his return from Austria, the Emperor Napoleon found on his desk at the Prefecture of Metz a Sarreguemines inkstand which attracted his attention, and which caused the Emperor to send for Mr. Utzschneider, in order to give him an important order for some of his goods, and some portions of this

special commission have since been seen at the Tuileries, at the Grand-Trianon, at the Cathedral of Spire, and other places. At the end of his interview, Mr. Utzschneider is reported to have been dismissed by the Emperor with these words: "Adieu. Succeed well. I like such men as you."

After forty-three years of activity at Sarreguemines, Mr. Paul Utzschneider retired, handing over the direction of the factory to his son-in-law, the Baron de Geiger, who proved his ability to keep pace with the growing reputation of this new Lorraine industry, and ten years later gained the Cross of the Legion of Honour. In 1855, at the Exhibition of Paris, the works of Sarreguemines were represented by a type of translucent porcelain on the lines of English china, which was offered in many styles of ornamentation—printed, painted, and decorated in various ways—as yet unique to France. There was also exhibited artistic earthenware, decorated both in underglaze colours and onglaze enamels. In 1864 the Baron de Geiger retired, entrusting the administration of the factory to his son Paul, who, some three years later, caused history to be repeated by himself meriting the Cross of the Legion of Honour, following upon the Paris Exhibition.

Effectually separated from France by the war of 1870, the Faienceries de Sarreguemines, under the general direction of M. de Geiger, in order to conserve a place in the French Republic, established an additional earthenware factory at Digoin, and later created still another at Vitry-le-François. In 1900 the combined wares of the firm carried off the Grand Prix at the Paris Exhibition. M. de Geiger died in 1913, leaving the control of the respective French factories to his son Alexandre de Geiger and his son-in-law M. Malval, whilst the factories at Sarreguemines were entrusted to M. Max Jaunez.

Coming down to more recent times, on the outbreak of the war, the Faienceries de Sarreguemines employed 3,500 workers, and the total annual output of their products amounted to about 6,000,000 francs, one-third of this output being sold in Germany and the remainder in other European countries and overseas. Since the war the factories have never got back to their normal pre-war production, and the total number of operatives to-day is little more than 2,000. Even this number, however, is quite respectable, a fact that is borne in upon one when one remembers the large number of very small potteries which, in the main, go to comprise the great Staffordshire industry, and the very few pottery-producing firms in England who employ anything like so great a number of work-people as 2,000.

There are two quite separate factories at Sarreguemines, one on either side of a waterway which one discovered to be a canalised section of the river Saar. One of these works—the older of the two—was not visited, the time not permitting. This more ancient works was obviously designed very much on traditional Stafford-

shire lines, the buildings being two-story, and the ovens being of the old bottle-necked type. The name of Wedgwood has already been referred to in this article, and the influence of Wedgwood's practice upon the early activities of Sarreguemines seems to be reflected in many ways.

The older and more modern works at Sarreguemines are connected by a bridge, over which runs a broad-gauge railway track which promotes the fullest measure of transport of both raw materials and finished goods, and links up the two factories very effectually. Crossing over the canal by means of this bridge, we were brought face to face with a factory of an ultra-modern type, and one which, from an organisation point of view, appeared to be as near perfection as modern knowledge of factory lay-out will allow. The entire place was seen to be laid out on the single-story principle, and under a single roof. Every individual department of the works seemed to be sequentially situated, one department simply abutting another, and, although distinct and separate, never divorced from other departments to which it was closely related. The whole comprehensive process of manufacture can be taken in by the eye at a glance, and the various foremen as well as the works' manager are able in this way to keep a close surveillance upon what is going on. Potters, printers, dippers, stencillers, aerographers, placers and sorters thus all work under one common roof, and around this huge workshop of many sections are situated the ovens and kilns, which can be seen being placed and drawn at the same time as one is inspecting the various manufacturing processes.

Under an arrangement such as that which Sarreguemines can boast of, the wasteful carrying of ware from point to point is entirely obviated. The articles simply force their way through the factory from the making end to the sorters and packers. This is a point to which British potters have yet to pay more attention. It was evident to all who inspected this particular pottery that whatever successes have been achieved by Sarreguemines are very largely due to the economies which have been embraced in production, for the average quality of the wares produced—in utilitarian domestic wares at all events, which represent the great bulk of the turnover—is of a medium and popular type, such as the great majority of Staffordshire potters are producing, day by day, year in and year out, without anything in the way of special effort. Again, one could not help noticing that the potteries of Sarreguemines are under the necessity of importing china stone and ball clay from England, so that clearly they have no special advantages in the way of raw materials.

In the clay departments of the factory, one observed several interesting details. Jiggers were seen being worked in some cases by the feet, as well as in other cases by electric drive. The profiles were attached to a weighted rope, so that after a plate was made, and whilst it was being taken off, the profile rose by gravity. Before

the war women plate-makers were not known at Sarreguemines; to-day, however, some eighty or ninety women are to be seen thus employed. Bare-footed boys we encountered busily engaged as runners, and that all concerned worked consistently hard was evident. Incidentally it may be mentioned that the working hours are eight per day, the factory commencing at a quarter to seven, a quarter of an hour being allowed at 8 o'clock for breakfast, and an hour and a quarter at mid-day for lunch. Work is resumed at 1-15 until 4-15, when those of the workers who reside at some distance from the scene of their work are taken home by train. This early finish allows those who wish to do so to put in some time afterwards upon their gardens, or to have a long evening's recreation. Situated upon a pleasant ridge closely adjoining the works are houses belonging to the firm, capable of accommodating about 800 of the workers.

A visit round the showrooms of the factory impresses one with the many-sidedness of the firm's operations. There is possibly not a single factory in England which would care to be troubled with such an immense variety of products. If one could imagine, gathered together in one collection, a little of the productions of almost every Staffordshire pottery, combined with a little of everything produced by the various out-potteries—Langley and Denby wares particularly—and further, ornamental wares with applied fruits, flowers and leafage such as were produced in Staffordshire thirty or forty years ago, one is able to get some slight impression of the diversity of the wares produced by Sarreguemines. The writer happened to suggest to one of the principals of the works that a such a wide dissimilitude of productions was rather calculated to nullify some of the economies realised by the firm in other ways. The point was conceded, and it was tacitly admitted that the variety is, in fact, far too great, and that an attempt is being made at the present time to reduce it somewhat.

It was not altogether surprising that quite a number of the visitors were anxious to hear from their guides as to what sort of an experience the factories met with at the hands of the Germans throughout the four years of the war, and especially during the period in which the fate of Alsace-Lorraine hung in the balance. The factories, we were informed, continued to work throughout, hampered only by a depletion of staff similar to that which took place in England. The German military authorities did not overlook, however, that the factories of Sarreguemines were allied to two similar factories in France, and they were consequently ever on the lookout for evidences of any deflection on the part of the factory administration from the path of rectitude in the direction of patriotism. On no less than three occasions Mr. Windergast, the administrateur, was hauled up before the War Council, and charged with being palpably French in his sympathies. On one occasion the subject of the charge was the production of a pair of statuettes, one of which

represented Alsace lifting up her eyes to heaven in an attitude of hope and faith for deliverance ; the other depicting Lorraine, with down-cast eyes, striking an attitude of dejection occasioned by the knowledge of her continued bondage. For this offence Mr. Windergast was summarily condemned to six months' imprisonment, but the sentence was subsequently mitigated by his agreeing to pay 2,000 marks for his freedom. "Believe me, we suffered much during the war," said Mr. Windergast to the writer in the course of a conversation which took place during the tour of the works.

After finishing our inspection of the factory, led by the principals, we wended our way along the side of the canal to a magnificently appointed casino, and in one of the club-rooms of the workers we were entertained by the proprietors to light refreshment. A very pleasant half hour was spent in social intercourse, and the opportunity was afterwards taken of inspecting the arrangements made by the firm for the social well-being of their workers. We found that, in addition to a concert-room, equipped with a full-size theatrical stage, there is a large ball-room, where dances can be held under the very best of auspices, and there is every facility for the playing of indoor games, and for indulging in various outdoor recreations. The whole of the interior of the building is beautifully lined with tiles produced at the factory, the entire aspect of the place being one of real sumptuousness. During the war the casino was used by the Germans as a military hospital, and a certain amount of damage was callously done by the troops quartered there, which, however, is gradually being put right. It was with regret that we learned that, on the reopening of the theatre after the war, the feelings of hostility between the operatives of French and German parentage were so acute that it was deemed advisable for a time to close the casino, and as yet it is not being used to the extent that it once was, and even the band which formerly occupied the adjoining pavilion has not yet been reconstituted. Sufficient has, however, been written to prove that welfare work is no new idea in connection with the Continental potteries, and obviously a good deal has yet to be done in this respect in England before we can come up to the arrangements above described.

Whilst we were resting for a while in the casino of Sarreguemines and its environs, a message was received from the Mayor (who had learned of the presence of the French and English visitors) inviting us to pay a visit to a small industrial exhibition which was taking place in the town. The invitation was eagerly embraced, with the result that several interesting items of machinery were seen in operation at this particular exhibition, and various other items of plant likely to be of some use to manufacturers. The writer was specially interested in a small display of pottery produced respectively at Sarreguemines, Digoin and Vitry-le-François, as well as some interesting glasswares, manufactured in Lorraine at the

works of the Cristalleries de Saint-Louis at Münzthal (Moselle). Incidentally it may be recalled that the valley of Münzthal has been identified with the manufacture of glassware since the year 1566, and the Cristalleries de Saint-Louis have been operating there since the year 1644. In 1788, they had four furnaces working, and engaged 400 workers, producing £40,000 worth of glass per annum. When the war broke out the personnel of the factories totalled 2,500 persons. How many workers the glass-works of Münzthal valley have been able to conserve during the war we are unable at the moment to say, but the high quality of their productions, and the wide variety of the lines produced, were reflected in the exhibit at the Sarreguemines "Fair." Some interesting glassware was also shown by the Verrerie de Meisenthal, situate in Lorraine.

Before leaving Sarreguemines luncheon was served at the Hotel de France, after which M. Guérineau, in the name of the French ceramic group, and Mr. W. Swinnerton Hawley, on behalf of the English contingent, each expressed thanks to the directorate of the Faienceries for their kindness in throwing open their works so freely and for the warmth of their hospitality. Mr. Hawley, in the name of the Ceramic Society, mentioned that if, at any time, Mr. Windergast or his colleagues had the pleasure of visiting England the Staffordshire potters would be happy to do their best to reciprocate the kind sentiments which had been displayed.

Mr. Windergast, acknowledging, said he hoped that some day he might be able to take advantage of that offer. He was always interested to learn of the achievements of the British potters. They could not hope, at Sarreguemines, ever to compete for the position which the English potters held as masters of their calling ; at the same time, he was glad to hear from one or two of the visitors that they admired the products of Sarreguemines, and he hoped all would carry away with them pleasant recollections of their visit.

Sarreguemines was left behind in the early evening, the journey being continued to Strasbourg, the capital of Alsace, where accommodation for the party had to be spread over four separate hotels, viz. : the Hotel de la Ville de Paris, the Hotel Maison Rouge, the Hotel National and the Hotel Christophe. The amenities of Strasbourg were found to be far superior to those of Metz, and the nearness of the town to the Rhine frontier was taken advantage of by some of us to make a flying visit over the bridge-head during the few hours that we were left to our own resources.

On Thursday, May 19, visits were paid to three distinct potteries, situated respectively at Soufflenheim and Seltz, both being villages in Alsace. Leaving Strasbourg by special train at 8 a.m., we reached Soufflenheim about 9 o'clock, and paid a visit in the first place to a factory engaged in the manufacture of two types of ware. One section of this particular pottery is devoted to the production of common redware flowerpots, the capacity of the works being said to be 70,000 flowerpots per day ; the other section

is engaged in the manufacture of refractory goods, and claims to maintain an output of such goods of about 20 tons per day. We were informed that the clay employed for the making of the flowerpots is obtained from a quarry about half a mile from the works, and that about two-thirds of the clay employed in the refractory works is also obtained locally, the other third being drawn from the Palatinate, a neighbouring German province. From the site of this works one was able to get a lovely view of the surrounding country, and to catch a glimpse of the Black Forest, which seemed to loom up like a dark cloud in the distance. At first sight the situation of the place seemed rather opposed to the prosecution of serious manufacturing pursuits, but first impressions did not prove to be correct, for the factory, on inspection, proved to be designed on truly commercial lines, and although it was not working at full pressure at the time of our visit, there were plenty of indications that its capacity is not circumscribed. Indeed, the Soufflenheim flowerpot works is one of the largest concerns making horticultural pots in France, and sends its products in full truck loads as far north as Paris, despite the fact that there are several works producing by hand situated rather nearer the capital. Soufflenheim also exports its flowerpots, so the writer was told, to both Holland and Switzerland, whilst it is clearly located sufficiently near to Germany to be capable of competing powerfully in that country, at all events in the Western provinces.

We have already hinted that this flowerpot works was not busy ; as a matter of fact, the capacity of it is so great that it can do much more than keep pace with the demand, and to avoid over-production operations have had to be temporarily suspended. We were informed that since the conclusion of the war the demand for flower pots, for some reason, has fallen away seriously, and last year the firm did not despatch more than about 50 trucks during the whole 52 weeks. However, a few presses had been set going in order to give us an idea of the mass production scale on which the factory operates.

The preparation of the clay, like every other operation, is performed with the minimum of labour. The red clay is first of all wetted, and thrown on to a belt conveyor, which elevates it to a perforated-bottom pan. Rollers squeeze the clay through these perforations, and scrapers at the bottom collect it, and discharge it into a hopper, from which it passes between several sets of rollers to a horizontal pugmill. On coming from the pugmill the clay is cut by wires into chunks, and passed on to power-driven flowerpot presses, where it is converted into flowerpots at a remarkably rapid rate. (The presses, which appeared to be extremely facile, were observed to be the product of the Société de Construction Alsacienne, of Grafenstaden.) The finished flowerpots are afterwards fired in a Belgian 26-chamber kiln, to a temperature of only about 900 deg. C. Above the kiln is a floor used for drying.

In view of the fact that this section of the factory was not working under normal conditions, little time was spent here, and we passed through to the refractory materials branch, which was of rather greater interest to some members of our party. It was noticed here that quite a variety of refractory goods was being produced, from ordinary firebricks and siliceous coke oven goods to special nozzles and poking hole blocks for use in blast furnaces. Considerable time was spent in the environs of the clay-mixing sheds, where it was observed that a mixture of clays is deposited into soaking pits, and is there allowed to soak thoroughly for several days. From these beds the clay is transferred to a special type of mixer—a trough about 4 ft. high, 4 ft. wide, and 14 ft. long. Measured quantities of grog were brought up by one of the sliphouse workers, who sprinkled the grog over the surface of the clay. At the end of the trough was a revolving shaft with bar projections, which broke off small portions of the mixture, causing it to fall upon a belt conveyor, which conveyed it to a pair of rollers, and from thence to the pug, where the clay was exuded. For some special purposes of manufacture the pugged clay was re-pugged in a separate pug mill. It was then placed on an endless conveyor which circuited the whole of the drying rooms and making shops. The makers simply took the clay from the automatic conveyor as they required it for the making of their particular articles, and in this manner all carrying of clay whatsoever was avoided. The conveyor in question, which only necessitated an expenditure of 8 h.p., not only conveyed the clay to the makers but also transported the dried bricks and setters to the kiln. The setting gang consisted of only two men, one lifting the bricks from the conveyor and passing them to his mate, who placed them in the kiln. When the bricks were drawn from the kiln they were loaded straight into railway trucks and conveyed by this means to the stack yards.

The firebricks, it was noticed, were practically all hand-made, and they were sand-moulded. The nozzles for blast furnaces were hand-pressed by means of steel dies. The ordinary fireclay goods appeared to be composed of a clay compounded from two parts of Gruenstadt German aluminous fireclay to one part of the local clay, which is apparently more siliceous. The steel furnace nozzles were said to be made at the rate of 130 per man per day of 10 hours, and it was stated that they were allowed to dry on the floor for 14 days. The poking hole blocks, on the other hand, took from 8 to 11 weeks to dry, and it was claimed by one of the workmen that they could then be kilned in 14 days from the time of setting to the time of drawing.

With regard to the firing, the smaller and medium size blocks are burned in the Belgian chamber kiln, and the larger blocks, which would be likely to hold up the rate of travel of that particular kiln, are burned in two separate kilns, each having two floors. The smaller of these two kilns has four fire holes, and the larger one

eight. The green blocks are set in the top chamber, and after being fired there are transferred to the bottom chamber, where they receive their final firing. (These double-decked ovens, which appeared to be of unique construction, are a product of Mr. Paul A. F. Schulz, oven and furnace builder, of Dresden.)

It would take up too much space to transcribe the whole of the notes which were taken in the course of the visit to this particular works, and to do so would probably be to weary the average reader. We will, therefore, close the account of this particular visit by remarking that the main feature, and the most impressive one, was doubtless the efficient organisation in the way of mechanical appliances and departmental inter-communication, as at other works which were visited during the tour. Human labour is apparently regarded on the Continent as too valuable to employ in duties which can be as well performed by automatic means. In short, the human element is only employed where the machine fails.

It was something of a relief to pay a visit for a brief period of not more than perhaps half an hour to a little works, situated not far from this more scientific plant which we have just been describing, where two or three rural potters were engaged, in an old raftered building which, except for its French windows, reminded one almost of Stratford-on-Avon, in the manufacture of a type of art pottery—*objets d'art*, as they describe them—in conjunction with a range of culinary items. Operating under the style of Elchinger & Cie., 5, Rue de la Gare, Soufflenheim, these primitive potters themselves make, decorate, and fire their commodities. On an upper floor of this rural tenement one was able to get right away from the idea of modernity and mass production, and enter into the spirit of the old-time potter, sitting bare-footed at his wheel, which he speeded up or slowed down at his whim and fancy by means of the sole of his bare foot, in the endeavour to keep pace with comparatively small orders for multitudinous shapes and sizes. After two days of rush and scramble to see all that was most up-to-date and time-saving, it was quite restful to get into the atmosphere of this old-world pottery, and to watch once more the potter's thumb squeezing up wreath after wreath of clay, letting it down again, opening it outwards, compressing it inwards, occasionally taking it into his head to squeeze up the whole piece into a shapeless mass with a gesture of impatience, and begin all over again, because he felt dissatisfied with it. There was nothing connected with this little pottery to put specially on record, unless it be to mention the æsthetic characteristics of it, as distinct from the coldly scientific spirit which one was able to discern in the whole of the other works that were visited.

The Soufflenheim station-master, probably not often troubled with special trains, got rid of his responsibility within two hours of his acceptance of it, and the journey was continued to Seltz,

where, on arrival, a capital luncheon was provided at the Hotel du Cygne. The journey to Seltz had been undertaken in order to see the flooring tile works belonging to Mr. A. Bisch, and on the conclusion of the luncheon this gentleman welcomed us warmly, remarking that it was 2½ years since the French once more entered Alsace and liberated it. After nearly 50 years of German domination, every one locally was most pleased at the restoration of Alsace to France. He was ready to give his visitors all possible information with regard to his operations, and he hoped they would have an enjoyable time.

M. Guérineau, on behalf of the French visitors, thanked Mr. Bisch for his reception, remarking that this gentleman was the first of the Alsatian manufacturers to send in his name as a member of the French Refractories Syndicate. Lt.-Col. C. W. Thomas also returned thanks, remarking upon what a great deal his particular section was learning from the visit.

Mr. Bisch's tile works at Seltz, which was visited during the afternoon, proved to be one of the finest pieces of works organisation that were encountered throughout the tour. The clays are drawn from Mr. Bisch's quarry about three miles distant, a private railway belonging to the works being employed. On arrival at the works, the clay is side-tipped into weathering pits, where it is wetted and allowed to stand for three to four weeks in order to improve its plasticity. When the clay is started on its trip through the works it is inserted into a perforated-bottom pan, from which it drops on to a belt conveyor, which lifts it into a pugmill. From the pug the clay is cut into clots by means of an automatic wire cutter which rises and falls alternately as each chunk is sawn off. This arrangement being automatic, the clots of clay are cut just the necessary size—neither more nor less—each piece being sufficient to make four tiles. On leaving the pugmill the chunks of clay pass to a conveyor belt, which moves at a faster rate than that at which the clay is exuded from the pug, the consequence being that a space is left on the belt between each chunk of clay. The slabs of clay are automatically carried by the conveyor belt to the tile-presses, where they are taken off by the operators as they require them for use on the press.

The tile presses are fitted with a horizontal shaft, surrounded by five dies to form a pentagon. Each of these five dies performs a restricted operation as the shaft performs its sectional revolutions, *i.e.*, as the first die is pressing out the rough contour of the tile the last one is facing another ready for delivery from the machine. As the tiles are finished they are taken off by the operator of the press and placed upon palettes, which are being constantly fed to the operator by gravity from an upper floor. Five tiles are deposited upon a mangle elevator on frame-dryer boards, constructed of 1½ in. by ¾ in. laths. These boards automatically rise to the floor above, and are there taken off from the elevator 22 boards at a time by

the iron arms of a truck which is brought close up to the elevator, and is operated by a hand lever. The entire arrangement is one of considerable ingenuity, as will be readily appreciated when one remembers that each of these large tiles weighs 8 lbs., that they are placed five on a board, and that 22 boards are removed *en bloc* from elevator to drying stove without being touched by hand.

The dryer was observed to be of a special type, arranged in a series of compartments, each capable of holding 4,000 tiles. The whole dryer was filled by means of the automatic carriers to which we have already referred, and 600 loads are required to fill the dryer completely. The dryer is situated over the top of the continuous kiln—a 14-chamber Hoffmann. When the tiles are dry they are taken from the dryer by the same means as they are conveyed thereto, which has already been described, the makers' palettes being returned to the pressing machine. When the tiles are drawn from the kiln, they are placed temporarily into small square trucks, and thence transhipped to the railway trucks or unloaded on the stacking ground. It was noticed that dried bulrushes were used for packing between the tiles that were packed into the railway trucks, a layer of bulrushes being laid between each layer of tiles. The whole of the foregoing description refers to the large Marseilles type of tiles, but the methods adopted for the making of the small flat tiles and the German pattern tiles were, in many respects, almost identical.

An interesting point that should be mentioned in connection with the work of the tile makers was that they are expected to make a stated quantity per day. As soon as they have made this quantity, they finish work and get away home. Residing in an agricultural country, most of the workers naturally have their gardens, and an arrangement of the kind mentioned gives the men an incentive to work well, finish up, and get away early.

The writer, who took the trouble to check some of his impressions in regard to this particular factory with one or two manufacturers of the coarser types of claywares, found that everyone seemed to be in perfect agreement that the works was one which revealed remarkable ingenuity in the way of contrivances for labour saving. To quote the words of one manufacturer: "What impressed me most of all was the wonderful balance of the entire process from the grinding of the clay to the loading of the finished goods, together with the compactness and consolidation into a remarkably small space of a big and thoroughly efficient plant. The manner in which all waste was reclaimed was also highly commendable. All the clay that was wasted in its course from grinding pan to pugmill was automatically thrown on to a conveyor belt and returned to the pugmill, and the waste that was occasioned in the tile pressing was dealt with concurrently with the making of every individual tile. Although the system might yet be subject to modifications of detail, the principle of it seems ideal."

We bade adieu to Seltz in the late evening, returning to Strasbourg, where the evening and the greater part of the following day were spent in sight-seeing. We took train at noon on Friday, May 20, for Paris, and reached the French capital after a 9½ hours' journey by express. One or two of our members took exception to this rather long journey, and elected to make the trip from Strasbourg to Paris by air. Although they gave us several hours start, we found them standing on the steps of the Hotel Palais d'Orsay to welcome us on arrival. They had already been in Paris some hours, and had changed, dined, and rested awhile before the main body of the party arrived. All of which gave rise to a discussion in the evening as to whether, in future, the Ceramic Society will not be well-advised to consider the possibility of making its excursions by this quicker means of transit.

The main portion of the programme of the tour was now completed, and on the following day, Saturday, May 21, the party lost its cohesion, for some of us took the early boat train via Boulogne for England ; others struck off on private courses of their own for the week-end, and a few remained behind in Paris to visit on the Monday the Sèvres porcelain works and the liquid gold factory of Messrs. Marret, Bonnin, Lebel & Guieu at Noisy-le-Sec. A few less easily satisfied, protracted their stay for nearly a week in order to visit the northern battlefields. But here our account of the trip must be brought to a conclusion.

It only remains to be said that the arrangements for the tour were capably carried through by Thos. Cook & Son, through the instrumentality of their Sheffield branch, who instructed Mr. W. F. Hodgson, one of their representatives, to accompany us throughout the whole tour so as to be on the spot to deal with any unforeseen difficulties that might arise. In order to facilitate railway travelling in Alsace-Lorraine, as has already been indicated, a special train was held at our disposal for three days, and wherever the main line services were utilised, the necessary reservations were made. Considering the large area that was covered in so little time, the arrangements were, on the whole, very satisfactory. The only way in which they might possibly have been improved would have been by resorting to sleeping cars and night travelling, which would have obviated the five o'clock risings and, incidentally, some of the missed breakfasts. But one cannot have it all ways.

The writer, and in fact the entire party, is personally indebted to Mr. W. Swinnerton Hawley, of the firm of G. Howson & Sons, Ltd., for his very valuable services from time to time in the capacity of interpreter, without which it would have been difficult to record many of the particulars of what was seen and heard, especially on the German side of the frontier.

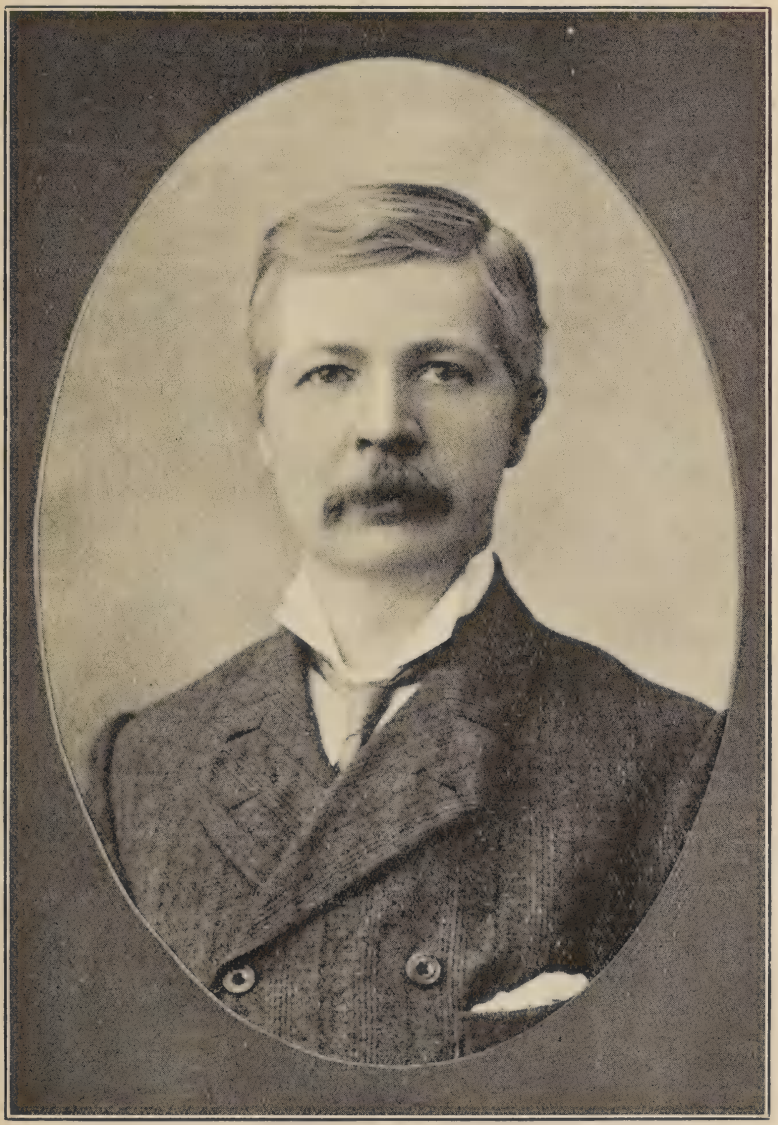
Mr. WILLIAM JACKSON, A.R.C.Sc.

ON January 10th, 1921, the Ceramic Society sustained the loss of its respected founder, Mr. William Jackson, A.R.C.Sc., an industrial chemist and scientist of considerable repute, who passed away at his residence, "Glenfield," Stacksteads, near Manchester, at the age of 57.

The late Mr. Jackson was born at Bacup, Lancs., and began life as a cotton weaver. His inclinations, however, were always in the direction of science, and by indomitable zest and continued application, he was successful, not only in capturing all the best prizes at the Bacup Science School, but in winning eventually a scholarship tenable at the Royal College of Science. After a successful course in London, he won a more important scholarship tenable at Zurich University, where he took his degree. Notwithstanding the offer of several lucrative appointments in Switzerland, he returned to England, and took up an appointment as science master at the Victoria Institute, Tunstall, where, in his spare time, he began to study the scientific factors which operate in connection with potting, and succeeded in making himself thoroughly *au fait* with this aspect of industrial chemistry.

After acting for some time as science master at the Victoria Institute, the late Mr. Jackson was induced to take up the duties of pottery instructor, in succession to Mr. Henry Watkin, the present managing director of the firm of Jas. Macintyre & Co., Ltd., Burslem, who, some little time before, had succeeded Mr. Wm. Burton. A small laboratory was established at the Victoria Institute, Tunstall, and it was here that the first definite move was made towards the establishment of classes in ceramic technology. The movement was at first regarded, if not with suspicion, at all events with extreme caution, and the remuneration of the instructor was all too small to retain so qualified a person as Mr. Jackson. Failing to obtain any support from the local educational authority in a proposal to pay a visit to the American potteries, which he was anxious to visit in order to widen his experience of practical details connected with pottery manufacture, Mr. Jackson eventually decided to visit America at his own expense. The result was that an attempt was subsequently made by a large American undertaking to secure Mr. Jackson's services, but the late Mr. Alfred Meakin prevented this by himself offering Mr. Jackson a suitable appointment. Having severed his connection with the Tunstall Pottery School, Mr. Jackson now turned his attention whole-heartedly to the chemistry of the pottery industry, and did some extremely useful work in this connection.

After the death of Mr. Meakin and the acquirement of the concern by Johnson Bros., Mr. Jackson transferred his services to the Patent Tile Works, Stoke, owned by Minton, Hollins & Co. His health, however, began to fail, and he was compelled to give up his pottery work and to look towards an open-air life. He accordingly went into retirement for a time at Kidsgrove. Then came the war, by which time Mr. Jackson's health was sufficiently improved for him to resume activities. He took a Government appointment at Hadfield, Lancs., as a superintending technical chemist, and there took charge of all the details connected with the purification and manufacture of large quantities of cotton to be used in the manufacture of cordite and other munitions of war. In exemplification of Mr. Jackson's active temperament, it is only necessary to add that, in addition to his other duties, he



Mr. WILLIAM JACKSON, A.R.C.Sc.

found time to devote to the teaching of chemistry at Rossendale and other technical institutions.

On the conclusion of the war the late Mr. Jackson purchased a glass and china business at Bury, which he carried on with the aid of a brother until his death.

Mr. Jackson was a sleeping partner in the Thermoscope Manufacturing Co., Hanley, the "thermoscope" having been jointly invented by himself and Mr. J. P. Holdcroft. Although he was an extremely modest man, and naturally reserved and diffident, Mr. Jackson's qualifications were highly appraised by all who were most intimately associated with him. He was unfortunate in the respect that his connection with the pottery industry commenced at a time when science was regarded as only useful for academic purposes—a hobby that was expensive and not thought to be at all necessary as applied to industry. In this respect he was twenty years ahead of his time.

The members of the Ceramic Society as a whole, and particularly those who were brought into contact with the late Mr. Jackson in his work twenty years ago, deplore the loss which the Society has incurred by his death, and pay a silent tribute to the passing of one to whom must be attributed the volition which brought so useful an institution into being.

H.T.

Mr. ERNEST MAYER.

On Dec. 11th, 1920, an old and greatly respected member of our Society passed away at the age of 63 years in the person of Mr. Ernest Mayer. He was born at Burslem in 1857, the son of Jos. Mayer.

The Mayer family has been intimately connected with the Staffordshire Potteries for a number of generations, and two of its members—Jos. Mayer, of Dale Hall, and Elijah Mayer, of Hanley—achieved no small measure of success. Their names are still familiar to all who are acquainted with the development of our industry. The Mayers are probably decended from the Meir, or Mayor, family of Derbyshire. John Meir was a pot maker in 1721, and there were several Mayers of Cockpit Hill in 1772. In Staffordshire, Hugh Mayer was a Potter at Burslem in the early part of the XVIII. Century, and at the beginning of last century, Hugh Mayer and J. Mayer were Potters in Hanley.

The Mayers were exceedingly clever potters, particularly Jos. who rivalled Wedgwood in the production of an excellent white ware, the colour and texture of which could not be surpassed. His work was unfortunately cut short by a premature death, due to excessive study and devotion to his art. Among the improved processes introduced by the Mayers may be mentioned that of printing in from two to five colours on biscuit ware.

Ernest Mayer, who left this country for America some forty years ago, was associated with a pottery at Baltimore, the Mayer China Co. being formed by the brothers Ernest and Joseph in 1881.

Mr. Ernest Mayer took a very active and prominent part in the social life of his district, and for several years he served as a Town Councillor at New Brighton (Pa).

As was to be expected from one so keenly interested in the industry, Mr. Mayer became one of the guiding spirits in the American Ceramic Society. His loss will be mourned with equal sincerity on both sides of the Atlantic.

I.—Some of the Difficulties Experienced in Maintaining a Pyrometer Installation in a Works.

By Robert S. Whipple, M.I.E.E., F. Inst. P.

THE high price of materials and labour is bringing into prominence more and more the need of effective temperature control. Many firms have now installed pyrometers in their works, but it is doubtful whether the majority of them are obtaining the maximum amount of help from their instruments. It may, therefore, be of service to try and consider what are the chief difficulties experienced in the maintenance of a pyrometer installation and the methods by which they can be either overcome or avoided.

When dealing with this subject I assume that some one person in the works is interested in the efficient maintenance of the pyrometer equipment, and that this person understands the principles underlying the instruments. Experience shows that machine tools cannot be maintained efficiently unless someone has them under his particular charge. The management selects the tool, the foreman generally decides the speed at which it is to be operated, but it is the workman finally who makes the machine efficient or not, by seeing that his cutters are sharp, and his work correctly set, and who takes all the other small precautions which, in the aggregate, make efficiency. We can use our tool analogy in considering the pyrometer installation, and the reasons why any pyrometer installation is not a success may, I think, be summarised as follows:—

(1) The wrong type of instrument has been installed,
(2) The instrument is not being used efficiently, or
(3) The instrument itself requires adjustment or correction.

Under one or other of these three headings nearly all the difficulties experienced in pyrometric work can be grouped. I think that at this point I should state that it is not proposed to deal with the difficulties met with in ceramic work only, but to consider the subject as it affects the larger number of users.

(1) *The wrong type of instrument.*

It is, I think, discouraging to assume that the would-be user has already selected his instrument, and I will suppose that he is still free to make his selection from the various types now on the market. It is always disheartening to scrap a tool before it is worn out, yet experience has shown that it is cheaper to replace an inefficient tool with an efficient one, and in pyrometry the same fact holds good. If the wrong type of instrument has been

selected, it will be found cheaper in the long run to scrap the unsatisfactory article and to replace it with an instrument more fitted for the job. Assuming the doomed instrument is a well-made one of its class, it will nearly always prove useful somewhere in the Works on an operation for which it is suitable. As in the case of the machine tool, the technical man can help the would-be purchaser with his advice. There are now a large number of engineers with experience in the heat treatment of materials who can advise on the best type of instruments for the particular problem. When considering an installation the purchaser must make up his mind first of all as to the accuracy with which it is necessary to make his temperature measurements, and secondly, whether he wishes continuous records of the temperature taken, or whether readings of the temperature only are required. In coming to a decision it is important to consider the value and type of the work passing through the furnace or kiln. In the greater number of cases the initial cost of a pyrometer installation is small as compared with that of the furnace, and of the charges placed in the furnace during a month. This, I think, may be specially emphasised in the case of a large kiln filled with saggars containing ware, or an annealing furnace charged with bars of high-speed tool steel. Experience shows that in the majority of cases it is advisable to install a recorder, especially where it is essential that the temperature over a given time should not fall below a certain value, or where the rate of heating or of cooling is important. Having decided whether or not a continuous record of temperature is required, the position of the instruments must be considered. It is natural that the Manager should like to have the recorder in his own office, but if it is only possible to install one instrument, I venture to think that it is not the correct position. It should be placed in such a position that the fireman in charge of the furnace or kiln can see the records without having to walk any appreciable distance from his work. If the instrument is readily available to the fireman, he soon regards it as a friend put in to help him, whereas if the instrument is in the Manager's office, he regards it as a policeman installed to see that he does not fail in his duty. This is an important difference in the point of view of the man, and the success of a pyrometer installation depends after all on the way the fireman regards the instrument, in very much the same way as the success of the machine tool depends on the goodwill or otherwise of the man operating it. The happy mean is to install two instruments in parallel, a recorder in the Manager's office and an indicator in the furnace room. The pyrometer is recording continuously except when a spring return switch is operated by the fireman to introduce the indicator into the circuit. The recorder circuit is broken for the few seconds during which the fireman reads the temperature on the indicator. Immediately the switch is released the pyrometer is re-connected to

the recorder. When high resistance instruments are used the indicator and recorder can be wired in parallel and used continuously, but they should be calibrated for the particular conditions (length of lead, &c.) under which they will be used.

The type of pyrometer has next to be decided upon and this decision can only be taken after careful consideration of the temperatures it is required to measure and the degree of accuracy to which they are to be measured. As a guide to the selection of the type most generally suitable for industrial purposes, the following suggestions may be of service:—

For temperatures ranging from:—

−200° to 700°C	..	The resistance thermometer.
0° to 1200°C.	..	The thermo-electric thermometer.
700° to 2000°C. (or upwards)	..	The optical, or the radiation pyrometer

From this it will be seen that the various types overlap, so that there is a considerable amount of selection. Resistance thermometers may be arranged to give an open scale throughout the whole of their temperature range, and are particularly valuable as standards of reference. Thermo-electric thermometers are being largely used, and owing to the various improvements that have been introduced during the last few years, have become instruments of precision, even in the workshop. Both the optical and radiation pyrometers have the great advantage that it is not necessary to insert them into the source of heat, so that assuming various precautions are taken, the temperature of a hot body can be measured either by the luminosity of the hot body, or by the radiation emitted by it

As a general rule it may be stated that in workshops for the measurement of temperatures between 300°C. and 1200°C. the thermo-electric thermometer should be used. For work requiring high accuracy at temperatures between 800° and 1200°C. thermo-couples made of metals of the platinum group should be employed. Experience has shown that the platinum, platinum-rhodium couple is the most satisfactory and may be used for temperatures as high as 1600°C. for short periods.

It is almost impossible to protect a couple from deleterious gases at this high temperature and therefore it is inadvisable to use it above 1200°C. for any length of time. The high price of platinum almost renders the platinum, platinum-rhodium couple an unobtainable luxury and the base-metal couple is largely taking its place. The base-metal couples in general use are the iron—constantan (constantan=Cu 60 Ni 40) and the nickel-chromium—nickel-aluminium (nickel-chromium=Ni 90 Cu 10, nickel-aluminium Ni 98 Al 2) capable of being used up to 1370°C.*

If it is wished to record continuously above 1000°C. then a

* This latter couple was originally developed by the Hoskin's Manufacturing Co., Detroit, U.S.A.

radiation pyrometer should be used. Direct readings may be taken by means of a radiation or an optical pyrometer. If the hot body is small, then an optical pyrometer must be employed.

When making a decision, it must be borne in mind that the particular type of instrument has certain limitations. In any case it is asking a great deal to insist on an accuracy of 0·1 per cent. (1°C. at 1000°C.), and an accuracy of this type can only be obtained by taking special precautions. Assuming that the most satisfactory type of instrument has been selected, a great step has been taken towards the efficiency of the installation.

(2) *The instrument is not being used efficiently.*

Here again, I think, it will be of service to assume that the instruments have not been installed, and to suggest precautions which, if adopted, will undoubtedly avoid a great many of the difficulties experienced by those who maintain pyrometric installations. Not infrequently the management has devoted a considerable amount of thought to the selection of the correct type of apparatus, and yet the results obtained do not justify the thought or expenditure incurred. The installation is obviously inefficient. Why? The reasons will most probably be found to group themselves under one or other of the following headings:—

(*a*) The destruction of the protecting envelopes of the pyrometer by excessive heat or mechanical breakage due to incorrect mounting in the furnace.

(*b*) By vibration of the support carrying the galvanometer of the indicator or recorder.

(*c*) Defective wiring or unsatisfactory connections.

(*d*) Dirt.

(*e*) Want of adjustment of the indicator or recorder.

(*f*) Carelessness in the handling of the instruments and inattention to details.

(*a*) Undoubtedly the great need in pyrometry work at the present time is a material from which the protecting tubes could be made, that, whilst being mechanically strong, would resist high temperatures. I would appeal to those who are interested in the making of fire-resisting materials, to bear in mind the need of a material from which pyrometer tubes could be manufactured. Porcelain is still the most satisfactory material. Until the outbreak of War, the best was made by the Royal Berlin Porcelain Manufactory. The Royal Worcester Porcelain Works have developed a material which is almost as good as the German article, and from the point of view of porosity is distinctly better.* Fused quartz is valuable up to 1000°C. It is mechanically stronger than porcelain because it is possible to make up thicker tubes in this material than in porcelain. It will also stand rapid changes in temperature very much better than the porcelain. Unfortun-

* Excellent porcelain tubes are now being made by a Japanese and by some of the American manufacturers.

ately it cannot be used for any length of time at temperatures above 1000°C. as it slowly devitrifies, becomes brittle and not impervious to gases. Tubes made of alundum and salamander are useful as outer or secondary protecting sheaths, but they are too porous to be employed as protecting tubes, especially if a platinum thermocouple is installed. Nichrome sheaths are being used successfully as secondary protecting tubes in several works. They are apt to break down in positions where sulphur is present, such as in coke-fired malleable iron furnaces, but in positions free from sulphur, they last for some time at temperatures as high as 1000°C. The serious drawback to the tubes is their expense and the fact that they are not infrequently porous. With the exception of the last named, all these materials are fragile, and therefore the method of mounting the pyrometer in the furnace is of great importance; the life of the pyrometer depends on the method of mounting more than on any other condition. In a large number of cases the management must be prepared to obtain relative rather than absolute temperatures of the materials in the furnace. In many cases this is not of importance, all that is required being the repetition of certain temperature conditions which have previously yielded satisfactory results.

There are many types of furnace, but it may be useful to discuss the method of mounting the pyrometers in a few typical ones as a general guide to the problem. Dealing first of all with some of the simpler forms of furnace, the small hardening furnace shown in Figure 1 may be taken as an example. The furnace is fitted with burners of the Bunsen type, burning gas at the normal gas pressure. In the example the furnace has two flues into which dampers are fitted. It is not easy to bring a pyrometer through the roof, but if a hole is made through the back, and the pyrometer T rests on a fire-brick on the floor of the furnace, it should be sufficiently protected from mechanical breakage. As a rule, it is advisable to screw a flange with a socket on to the sheet iron covering the furnace in order to hold the pyrometer in position. Very frequently a salamander or fireclay tube is attached to this socket so that the pyrometer itself slips into this secondary protecting sheath, the sensitive element of the pyrometer being protected by a quartz tube. In this way the pyrometer is doubly protected It is important to see that the fire-brick on which the pyrometer rests projects all round the fireclay tube. If this precaution is taken, and nothing is actually placed on the pyrometer, it should last for several years, assuming that the temperature never exceeds 900°C. The problem in the case of one of the large re-heating and carbonising furnaces, shown in Figure 2, is much more difficult owing to the flue passing over the roof of the muffle. The pyrometer must either be placed through the roof or through the side. The figure shows two pyrometers thus inserted. In the case of the one passing through

the roof, a ring of brickwork must be placed round the pyrometer in the flue, or if this cannot be done, a large fireclay tube must be inserted through the roof into the inner muffle. Whatever steps are taken to protect the tube passing through the flue, difficulties may be anticipated owing to the relative expansion or contraction of the two arches of the furnace. For this reason it is advisable wherever possible to insert the pyrometer through the back wall of the furnace. On the other hand, if the pyrometer is placed through the roof, it can, probably, be brought nearer to the work, and will give the mean temperature of the furnace to a higher degree of accuracy.

The correct heat treatment of the expensive alloy steels is of great importance, not only from the point of view of expense, but also from that of the mechanical results to be obtained from the treated material. For this reason it is important to bring the pyrometers as close to the work as possible, and in the case of long furnaces it is necessary to have two or three pyrometers in the furnace. Where the pyrometers are being lifted in and out of the furnaces frequently, it is important to protect them by outer steel sheaths. In Figure 3 the pyrometer is shown with some form of lifting gear, so that it can be easily raised from the furnace. In this connection the importance of exploring the temperature distribution in a large furnace before it is used should be emphasised. It is not uncommon to find differences of 30°C. between the temperature of the back wall and front of a furnace. In such a case the operator cannot be expected to do good work unless he knows the temperature distribution, and this should be determined by means of a pyrometer placed in various positions in the furnace. Knowing the temperature the work can be arranged accordingly, the heavy work in the hot positions, the light in the cooler positions of the furnace.

One of the most difficult types of furnace in which to install a pyrometer is that used in the heat treatment of malleable iron. The iron parts are packed into iron boxes which are stacked into the furnace. The loading and unloading of the furnace—which is usually carried out by unskilled labour—makes it imperative that efficient mechanical protection should be given to the pyrometer. Experience has shown that the pyrometer is best supported on fire bricks built into the side of the furnace, as shown in Figure 4. In a pottery kiln the problem differs from the other examples, in that two different types of pyrometers have to be used to cover the complete range of temperature. The control of the temperature during the early or drying stages is of importance, and a thermocouple is generally used for this stage, and in the later stages of heating, a radiation pyrometer. It is usual to insert into the kiln a closed fire-clay or fused silica tube about 5 in. in internal diameter and 4 ft. long (see Figure 5). In many cases this tube is built into the door of the kiln with the closed end resting on a broken

saggar inside the kiln, so that as far as possible, the temperature recorded is the actual temperature to which the ware inside the saggars is exposed.* In the early stages a thermo-couple is inserted into the closed tube and in the later stages—after 700°C. has been reached—a radiation pyrometer is sighted on to the lower part of the tube.

The control of the temperature in a glass melting furnace is of great importance. The temperature of the molten glass (about 1600°C.) is so high, and its action is so destructive to the majority of materials that it is not commercially possible to insert pyrometers into the glass. Good comparative readings can, however, be obtained by the insertion of a closed silica tube, as shown in Figure 6. A Féry radiation pyrometer is sighted on the bottom of this tube, and the readings obtained approximate closely to those of the molten glass. The readings are admittedly only relative, but experience shows they are of great service.

If a pyrometer is to withstand extremely high temperatures, it must either be mounted vertically through the roof of the furnace, or supported horizontally thoughout its whole length. If it passes through a flue and is subjected to high temperatures throughout part of its length, it is advisable to use a platinum platinum-rhodium couple. Trouble and expense will be saved in the long run by doing so. If the temperatures are high, and it is not possible to use a radiation pyrometer, then it is best to compromise by inserting a pyrometer in some position (if such can be found) where the heat is not so great as in the main body of the furnace, and by working with comparative temperatures. It is fortunate that in nearly every case it is possible to use pyrometers of one type or another for the continuous record of all prolonged industrial heat-treatment processes. The determination of the melting and casting temperatures of metals and their alloys is a much more difficult problem, and a great deal of experimental work is still required to put this subject on a satisfactory footing.

(*b*) Assuming that the pyrometer has been installed, the mounting of the galvanometer requires consideration. If there is no serious amount of dirt or vibration, then, as previously mentioned, the instrument should be placed as close as possible to the man operating the furnaces.

Vibration is rarely serious in a works, especially if it is in a vertical direction. The galvanometer needle may swing up and down, but if there is no serious horizontal motion, the readings obtained are unaffected. At the same time, care must be taken to see that the coil is swinging freely. In the case of a suspended instrument, a want of level in the adjustment may be serious in that it causes the coil to foul the pole pieces of the magnet.

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*See "Pyrometry as applied to the making of Pottery", R. S. Whipple. TRANS. *Eng, Cer, Soc*, **12**, 202, 1913.

(*c*) Defective connections in the electrical circuits yield the most insidious errors. It does not matter what type of electrical thermometer is used, an intermittent contact or a varying resistance always introduces an error, sometimes one of considerable magnitude. The instrument may apparently be operating satisfactorily, whereas in reality it may be reading much lower than the true temperature. For this reason the wiring connecting the instruments and pyrometers should be carried out as well as possible. All connections should be soldered or made inside junction boxes. All switches used should make good surface contacts, and should be of good quality. In no case can there be a more striking example of "the ship being spoilt for a ha'porth of tar," than that of a whole pyrometer installation being ruined for the want of proper connecting leads or inferior switches.

(*d*) Dirt is the great enemy to all recording instruments, and too much care cannot be taken to see that the case of the recorder is kept as free from dirt as possible. In an iron works the dust is often magnetic and the iron particles which enter the recorder case are apt to adhere to the poles of the magnet, thus preventing the free movement of the galvanometer coil. It is advisable, therefore, to mount the recorders in an outer protecting case or cupboard if they have to be installed in a dusty position.

(3) *The instrument itself requires adjustment or correction.* I have, up to the present, discussed the selection of the types of instruments to be used, and their installation, but I have not mentioned the question of the corrections to be applied or, may I say, the scientific precautions to be taken, in order that the instruments may read correctly. The ultimate standard of all thermometry is the gas thermometer, filled, if it were possible, with a "perfect" gas, but at the present time the final standard is the Gas Thermometer at the Bureau International des Poids et Mesures at Sèvres, and it is to this standard that all thermometer measurements are finally referred. The thermo-electric scales of the instruments at the various National Physical Laboratories are known relatively to the instruments at Sèvres, and against these standards the auxiliary standards are finally compared. It is of interest to note that the determination of the freezing and boiling points of pure metals and other substances has become the most accurate method of intercomparing the various thermometric standards of the world. In a works equipped with a laboratory having facilities for testing its thermometric apparatus, any new instruments will naturally pass into the laboratory for test before going into the works. It may be of service to consider the thermometric equipment of such a laboratory, assuming that the apparatus is used for testing the workshop instruments rather than for research work in the laboratory. In the large laboratory the research instruments will doubtlessly be used for testing the substandards against which the workshop instruments are compared. In a small

laboratory the standards may well consist of the substandards of the larger one. In both cases it is advisable that the standards should be sent to the National Physical Laboratory. The first-class instrument maker welcomes the testing of his apparatus by the National Physical Laboratory, as he feels that the tests enable him to maintain a high standard of accuracy in his own workshop, in that any error that may have crept into his own standardizing apparatus is soon detected. The substandards having been tested at the Laboratory, the user knows that he can then link up his thermometric system to the accepted temperature scale. The importance of this is obvious. A manufacturer buys some special American steel, the maker of which specifies a definite heat treatment. The purchaser knows that, if the maker states that the steel should be annealed at a given temperature, he will be able to reproduce that temperature in England, although the manufacturer measured his temperatures with a pyrometer made in the United States, the readings of which were dependent on values given by the Bureau of Standards at Washington.

In a large laboratory it is advisable to have an accurate potentiometer, moving coil galvanometer, standard cell and two or three standard platinum—platinum-rhodium thermo-couples. In addition to these instruments it is advisable to have some form of workshop potentiometer containing a portable galvanometer and cadmium cell, which can readily be carried about the works, and which would generally act as a substandard. In the laboratory of the small works this instrument may be used as the standard. If expense is not a serious question, it is well to have a resistance thermometer with some form of bridge or indicator for checking the lower temperature points from 0 to 800°C. It has the advantage that the scale is open and the instrument capable of high accuracy. If at any time it is not convenient to send the laboratory standards to the National Physical Laboratory for standardisation, they may be checked by determining the boiling or freezing-points of various substances. There is little difficulty in taking the two fundamental points of the temperature scale, viz., the freezing and boiling-points of water; the former is taken by placing a thermometer in broken ice placed in a double-walled vessel, or a thermos-flask, and the latter by putting the thermometer into a simple form of steam hypsometer. When taking the boiling point it should not be forgotten that the boiling point of water varies with the barometric pressure. For higher temperatures, it is advisable to use the freezing points of pure metals, or of eutectic alloys and the freezing points of pure salts. The following will be found useful and satisfactory points:—

Freezing-point of Tin	231·8°C.
,, ,, ,, Lead	327·4°C.
,, ,, ,, Zinc	419·4°C.*

* The freezing point of zinc is a particularly useful point; it was found that determinations made on a sample continuously for six years in one crucible gave strictly consistent results.

Boiling-point of	Sulphur	444·7°C.
Freezing ,,	,, Antimony	630·7°C.
,,	,, ,, Sodium Chloride ..	800°C.†
,,	,, ,, Silver	960·8°C.
,,	,, ,, Copper	1083·0°C.

If high temperatures requiring the use of optical or radiation pyrometers are being used in the works, then it is advisable to install a small gas-heated muffle, or an electric tube furnace for the standardization of these instruments.

Assuming that the laboratory is equipped, it will be useful to consider the errors that may be met with in the works. With the exception of mercury-in-glass thermometers, there is little doubt that the thermo-electric instruments are the most generally used in a works, and the errors that may be met with in these thermometers should be considered. The majority of them fall under the following headings:—

(1) Error due to the gradual change in the E.M.F. of the couple.

(2) Error due to the temperature of the cold-junction being unknown or uncertain.

(3) Error due to the resistance of the leads or defective connections.

(4) Error due to the temperature of the indicator and to change in the galvanometer itself.

(1) Assuming that the couple is made from well-annealed and well-selected wires, little difficulty will be experienced in industrial work with regard to a change in the constants of a couple itself. The E.M.F. of nearly all the thermo-couples in general use remains remarkably constant after prolonged heating, even in cases where the element has become badly oxidized. The E.M.F. of the platinum—platinum-iridium couple falls slowly after prolonged exposure to about 1100°C. owing to the volatization of the iridium, the iridium contaminating the pure platinum side of the couple. For this reason the platinum—platinum-rhodium couple has almost entirely replaced the iridium one. Wherever possible, it is advisable to protect the thermo-couple (whatever the materials of which it is made) against oxidization and the action of furnace gases. As previously explained, either glazed porcelain or quartz should be used for this purpose.

(2) The most serious error met with in industrial thermo-electric pyrometry is undoubtedly that due to the uncertainty in the cold-junction temperatures. The resultant E.M.F. given by a couple depends upon the difference in the temperature of the hot and cold junctions. In the original calibration of the couple the cold-junction was maintained at a constant temperature

† The freezing point of common salt (NaCl) 800° is an extremely useful point, as small variations in the purity of the material make practically no difference in the freezing point. The salt is very volatile at this temperature and can be safely handled in an iron pot. The fumes are unpleasant and the experiment should be made in a well-ventilated room

(most likely 0°C.), the hot-junction being heated to certain definite temperatures. The E.M.F. generated at these temperatures was measured, and hence the constants of the couple determined. It is thus essential, when measuring the temperature of the hot-junction of a couple by the measurement of the E.M.F. given by it, that the cold-junction temperature should be known. It may be assumed that the galvanometer to which the thermo-couple is connected is placed in a spot which is not abnormally heated nor subject to great variation in temperature. The temperature of the galvanometer is then taken as the cold-junction temperature. Owing to the costliness of the material and sometimes to its high specific resistance, it is not possible to connect several of the pyrometers directly to the galvanometers with the same materials of which the couples are made, and various alloy wires have been suggested for this purpose. In the case of the platinum thermo-couples, the most satisfactory material is one invented by Peake, in which a comparatively inexpensive alloy of copper-nickel yields the same E.M.F., as the platinum,—platinum-rhodium couple.* In the case of some of the base-metal thermo-couples, other alloys have been evolved, so that compensating leads can be used with them. If compensating leads are used, then the point at which the compensating leads terminate becomes the cold-junction of the thermometer circuit. If it is desired to obtain high accuracy then the temperature of this point must be controlled. The simplest way of doing this is to use a thermos flask filled with oil, into which the cold-junction of the thermo-couple or of the compensating leads is placed, the point at which the copper leads join the couple being placed near the bottom of the flask. In practice, it will be found that the temperature of the surrounding air may change by 20°C. during 24 hours, and yet the temperature inside the flask remains constant to within 1°C Another effective way of controlling the cold-junction temperature is to bury the junction at a depth of 10 to 12 feet below the floor of a building. This will be found a simple but effective method of maintaining the cold-junction temperature constant to within 1 or 2°C. during the year.

When initially setting up the galvanometer the zero of the pointer should be adjusted for the temperature of the room. The pyrometer circuit is broken, either by disconnecting a wire from one of the terminals or by means of a switch provided for the purpose. The temperature of the instrument is taken by means of a mercury thermometer placed upon it and the needle of the instrument adjusted to that temperature by the rotation of the adjusting head. It is advisable to correct the zero in this manner whenever fairly accurate measurements are being made. Some makers do not fit a zero adjustment to their instruments, but

* The invention of compensating leads was originally due to Bristol, but the introduction of the low resistance copper-nickel leads was due to W. H. Peake.

calibrate for a temperature of 20°C. In such cases a small correction is required if the temperature of the instrument is above or below 20°C.

(3) When a galvanometer is calibrated for use with a thermo-couple, it is assumed that a definite resistance is in the circuit and it is essential that approximately the same resistance should be maintained in practice. The relationship of the resistance of the thermo-couple and its leads to that of the galvanometer has been for some years a vexed question. If the thermo-couple itself is a long one, and of high resistance, and its length is subjected to variation in heating, then the relationship of its resistance to the rest of the circuit is of importance. In such a case, the galvanometer should have a high resistance in order that the variations in the resistance of the circuit should bear a small ratio to the total resistance of the circuit. In general, it may be stated that the variation in resistance of the circuit, due to the causes mentioned, should not exceed 2% of the total resistance of the circuit. Where a low resistance galvanometer is employed, the manufacturer should be told the approximate resistance of the complete circuit, in order that he may calibrate the galvanometer accordingly.

(4) In addition to the fact that it is largely independent of the resistance of the circuit, a high resistance galvanometer has the advantage that its constants are practically unaffected by its own temperature. Taking a typical case where the moving coil resistance is 60 ohms and the manganin balancing resistance 940 ohms, the temperature coefficient of the galvanometer is approximately ·02% per 1°C. neglecting the effect of temperature on the control spring and magnet which is small in both cases. On the other hand, if a low resistance galvanometer is used, the forces available on the coil itself are greater, and the instrument can be more robust. In practice, a compromise has been reached, and galvanometers having a total resistance of about 80 ohms for rare metal and about 300 ohms for base-metal couples have been found best in general industrial work.* In research work requiring high accuracy, a high resistance galvanometer of 1000 ohms (copper 60, manganin 940) may be used, the lead resistance forming only a small percentage of the total resistance.

The potentiometric method of measuring the E.M.F., overcomes any difficulties with regard to lead resistance, and is undoubtedly the most accurate method of measuring temperatures with a thermo-electric couple. Although this method has been in use for scientific work for some years, it is only comparatively

* The error introduced if a galvanometer is heated above the temperature at which it was calibrated, is serious only when accurate work is being carried out, e.g., if an instrument having a resistance of 300 ohms (moving coil, copper, 40 ohms, balancing resistance, manganin, 260 ohms) was calibrated at a temperature of 15°C, and it was being used in the works when it was heated to 50°C, the error introduced—assuming the thermometer was at a true temperature of 700°C—would be 12 C; that is to say, the temperature shown on the instrument would be 688° instead of 700°C.

recently that it has been adopted industrially. There are now both in this country and America, several forms of workshop potentiometer in which temperatures can be measured with the minimum amount of trouble. Figure 7 shows an instrument which contains a galvanometer, standard cell and accumulator. The E.M.F.'s given by the thermo-couple are shown directly on a scale reading to 0·0001 volt over a range of 0 to 90 millivolts. In practice it will be found that a temperature can generally be obtained in a minute from the time of connecting up the thermo-couple. Works of any size should undoubtedly possess some form of potentiometer for checking the constants of its couples and galvanometers. It forms a useful substandard, and will often decide the question as to which of two couples is correct, or whether the couple or galvanometer is at fault, the reading on the potentiometer being obtained by balancing the E.M.F., given by the couple against that given by a standard cell. The arrangement is practically independent of any changes that may take place in the sensitivity of the potentiometer galvanometer. The method has the drawback that the readings are intermittent in that they are taken only when an electrical balance is obtained. For this reason, it is doubtful whether the potentiometer can replace the direct-reading instrument in the workshop.

Mention has been made of the effect of temperature on the galvanometer owing to the temperature coefficient of the instrument, but in practice this is not the most serious effect of overheating the instrument. The galvanometer coil is, after all, a delicate piece of mechanism, and can be easily distorted by overheating, and yet, not infrequently, an instrument is expected to work continuously when heated to temperatures as high as 50 to 70°C. As previously explained, serious errors may be introduced if the galvanometer forms the cold-junction of the circuit, and for these reasons it is imperative that the galvanometer, especially if it is a recording one, should not be overheated. This may, in some cases, necessitate using long leads to connect the pyrometer to the instrument, but if compensating leads are employed, there is no serious disadvantage, and, not improbably, the instrument will be in a less dusty position.

In the case of resistance thermometers, the same general precautions as to the insertion of the pyrometer in the furnace, and the importance of good connections in the electrical circuits, hold good. There are two methods in general use for the measurement of the resistance of thermometers. In both methods the thermometer coil forms one arm of a Wheatstone bridge, no current passing through the galvanometer (which is placed across the bridge) when the thermometer coil is at a specified temperature. In one method—the deflectional—the galvanometer is deflected when the temperature of the thermometer rises or falls, the scale being divided directly in temperature values. In the second

method—the balance or "Null"—the resistance in the other arm of the bridge is varied either automatically, or by hand, until balance is restored. The first is generally the more convenient if a comparatively contracted scale is no drawback. In this case the resistance of the thermometer is high, say 80 ohms at 0°C., and compensating leads are not required. This has the advantage that, as only two connections have to be made or broken when connecting or disconnecting a thermometer to the galvanometer, the method lends itself readily to a large number of thermometers being connected through a switchboard to one galvanometer.* As the method is a deflectional one, the amount of the deflection depends not only on the resistance of the thermometer, but also on the current in the circuit. It is therefore necessary to standardize the circuit by adjusting the current in it by means of a rheostat. An effective alternative over a small range is to alter the magnetic flux across the gap of the magnet of the galvanometer by means of a magnetic shunt, thus by increasing the magnetic flux across the gap a falling off in the E.M.F. of the battery can be compensated for. In the deflectional method the sensitivity of the arrangement should be standardized at least daily, and if a great many readings are taken throughout the twenty-four hours, at more frequent intervals. The instruments are so arranged that the standardization can be made without difficulty.

In the "Null" method these precautions are unnecessary. It may almost be affirmed that if the apparatus is working it is reading correctly, assuming, of course, that the thermometer and its leads are in good condition. It is only necessary to see that the E.M.F., of the battery does not fall below a specified amount. On the other hand, as generally arranged, the thermometers used in the "null" method are fitted with compensating leads, and it is not so easy to arrange for a large number of thermometers to be read in one central spot. The "null" method has also the drawback that a temperature cannot be read until the mechanical act of balancing has been performed either by the observer or by the instrument. In all resistance thermometer measurements the temperature of the instruments themselves is of little importance as compared with that of the instruments used in thermo-electric work. With the deflectional method the instrument is automatically compensated when the daily calibration is made, and in the "null" method the instrument is practically independent of temperature.

With pyrometers depending for their reading on the amount of radiation received from the hot body, we encounter an entirely fresh group of difficulties. These pyrometers may be divided into two classes—those depending on the total radiation emitted by the hot body, and those on the luminous radiation. The former

* When a large number of thermometers are read on one galvanometer by means of a switchboard, they are generally connected to a common return lead so that only one connection has to be broken.

are generally referred to as radiation pyrometers, the latter as optical. The intensity of the light emitted by a hot body varies immensely with its temperature, and therefore, at the first glance, one would assume that the easiest way to measure a temperature would be to compare photometrically the light emitted by the hot body with that emitted by a second hot body at a definite temperature. This would be the simplest way of doing so, if all bodies at the same temperature emitted the same amount of light, but unfortunately, such is not the case, the light, for example, from incandescent iron and carbon being much greater than that from porcelain or platinum at the same temperature.

Kirchhoff first propounded the idea of a "black body" as being a body which would absorb all radiations falling upon it and would neither reflect nor transmit any. He also showed that the radiation from such a black body is a function of the temperature alone, and was identical with the radiation inside an enclosure, all parts of which have the same temperature. It has already been mentioned that iron, carbon, etc., do not emit the same amount of light when heated to the same temperature. If, however, they are heated inside a black body—and the ordinary commercial furnace practically fulfills black-body conditions—then they will all emit the same radiation, and if looked at through a small opening in the furnace they will appear of uniform brightness. It is thus possible with a furnace fulfilling black-body conditions to determine its temperature from the energy radiated.

Radiation and optical pyrometers are usually graduated to give the true temperature of a body when under black-body conditions, that is, when it is completely enclosed in a furnace the walls of which are at the same temperature as the body. A pyrometer graduated to give the correct reading under black-body conditions is often said to read the "black-body temperature," which means that it then gives the true temperature, and in other conditions will not do so, the readings being too low. The difference depends on the composition of the hot body and on how much the conditions of the experiment vary from those of a true black-body. It will be found that the apparent temperature of any material when away from black-body conditions will always bear a fixed relationship to its true temperature. For example, the black-body temperature of a piece of iron at 1,200°C. will be 1,140°C., and that of porcelain at the same temperature 1,100°C. I will not enter here into the theoretical side of the subject, but would refer anyone interested to the excellent text books that have been published on the subject.*

Discussing first of all pyrometers depending on the total

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* "Methods of Measuring Temperature," Ezer Griffiths, Chapters V. and VII. C. Griffin & Co.
"The Measurement of High Temperature," G. K. Burgess, page 238. J. Wiley & Sons.
"Pyrometry," C. R. Darling, Chapter IV. E. & F. N. Spon, Ltd.
"Practical Pyrometry," E. S. Ferry, G. A. Shook and J. R. Collins, Chapters IV. and V. J. Wiley & Sons.

radiation emitted by the hot body, three pyrometers are in general use, the Féry, Foster and Thwing. These are all of the same general type, namely, the radiation from the furnace is concentrated by means of a reflector on to a thermo-couple, and thus the E.M.F. given by the couple varies with the radiation falling upon it. The amount of radiation has been shown to vary with the fourth power of the temperature. The observer may assume, when he receives the pyrometer from the maker (especially if the instrument has been standardized at the National Physical Laboratory) that the instrument indicates true temperatures if it is sighted on a hot body under "black-body" conditions. As explained above, the ordinary industrial furnace practically fulfills these conditions. The closed fireclay or quartz tube built into a furnace gives almost ideal conditions. If these conditions can be maintained in practice, then there is little question of differences in the temperature of a furnace as shown by a thermo-couple or radiation pyrometer. It is only when these conditions are departed from that the difficulty arises. If it is attempted to take the temperature of a crucible of metal in the open with a radiation pyrometer, then the temperature indicated will differ from the temperature shown by a pyrometer immersed in the metal, the difference between the two depending upon the particular metal in the crucible and the conditions of the experiment. After all, this may not prove a drawback. In the majority of operations it is a question of repeating given conditions, and if a process is successful when a certain apparent temperature is reached, it is of little moment what is the actual temperature, as long as it can be repeated. If it is always borne in mind that the instrument can only read correctly when certain conditions are fulfilled—and fortunately in the majority of cases in industry they are so fulfilled —then the radiation pyrometer is capable of great service. It has the advantage that it can be permanently installed to record temperatures (see Figure 5), and the readings are given directly on a dial or on a record sheet, thus eliminating the personal equation of the workman. So long as the image of the hot body formed by the concave reflector is sufficiently large to cover the small thermo-couple in the pyrometer, then the instalment is independent of the distance between it and the hot body. It is only a matter of calculation to determine the size of the object and the distance the Féry pyrometer should be mounted from it.*

For a standard Féry pyrometer, Burgess & Foote give the following dimensions:—

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* The relation between the size of the hot body and image formed by a concave mirror is

$$O = I\left(\frac{u}{f} - 1\right)$$

where O is the diameter of the hot body, I, that of the image, u, the distance of the hot body to the mirror, and f the focal length of the mirror. See "Methods of Measuring Temperature," Ezer Griffiths, page 91.

Distance from the hot body to the pyrometer	Diameter of hot body
70 cms.	1·2 cms.
80 cms.	1·4 cms.
100 cms.	1·8 cms.
150 cms.	3·1 cms.
200 cms.	4·2 cms.
300 cms.	6·3 cms.
500 cms.	10·7 cms.

When installing a recording Féry pyrometer sighting on the bottom of a closed tube inserted into the furnace, it is important to see that the outer end of the tube does not cut off any of the radiation received from the lower end. The tube should not be less in internal diameter than 10 cms. It is important to see that dirt does not settle on the mirror, as it lowers its reflecting power. In a permanent recording installation where there is much dust in the atmosphere, this is a difficulty which must be guarded against. A glass window is an efficient protection against dust, but the instrument must be calibrated at not less than three points over its range with the window in position. It is not sufficient to calibrate at one temperature only, as the absorption of the heat radiation by the window varies at different temperatures. A mirror may be tarnished to a considerable extent without seriously affecting its reflecting power of the long wave-length radiations and the greater part of the energy reflected is of long-wave length.

Pyrometer mirrors made of stainless steel are proving satisfactory. They are practically unbreakable and untarnishable; being hard, they can readily be polished without scratching.

The previous remarks with regard to the importance of "black-body" conditions hold good generally with regard to optical pyrometers, although they are not of such fundamental importance as in the case of the total radiation instruments. If the temperature of a "black-body" has been adjusted till the standard lamp of an optical pyrometer and the "black-body" have the same apparent brightness when light of a known wave-length (generally. 065μ), is used, then if the pyrometer is sighted on another body also radiating under "black-body" conditions the ratio of the temperatures of the two bodies can be obtained. It may be stated generally that the "total brightness" of a body varies with the fifth power of its temperature.*

The two common forms of optical pyrometer are the "disappearing filament" and the "polarizing" types. The former was originally invented by Morse, and perfected by Holborn and Kurlbaum. It is in very general use in the U.S.A. The instrument is a telescope in which the image of the hot body is focussed

* For a full discussion of the formulæ on which the scales of optical pyrometers are based, see "Methods of Measuring Temperature," Chapter 7.

in a plane containing the filament of an electric lamp. The current in the lamp is varied until the filament disappears against the image of the hot body. A red filter glass is fitted over the eye-piece to give monochromatic illumination. In using this instrument, care should be taken to see that the lenses are clean and that the lamp has been well aged before being used in the pyrometer.

In Great Britain and on the Continent the polarizing type is largely used. It consists of a spectro-photometer in which a monochromatic beam of light from the furnace is matched against one obtained from a standard electric lamp. The current through the lamp is adjusted by means of a rheostat and ammeter. The intensity of the beam given by the lamp is matched against that from an amyl acetate lamp by adjustment of the current passing through the lamp. This renders the scale of the pyrometer independent of the permanency of the electric lamp. The observer has thus a ready method of standardizing his pyrometer at any time. It is important to see that the small ground glass screen, used in front of the amyl acetate flame to give an evenly illuminated field, is clean.

To check the calibration of an optical or radiation pyrometer a "black-body" furnace of some kind must be employed. A tube furnace, electrically heated, or a small gas muffle may be used up to temperatures of 1200 to 1400°C., depending on the type of furnace. A standard thermo-couple is mounted on the face of a small block of fireclay or quartz placed inside the muffle, and the pyrometer is sighted directly on to the couple or into the mouth of the muffle. The apparent temperature, as shown by the optical or radiation pyrometer, is then compared with the readings given by the thermo-couple at various temperatures. The results are then plotted and the corrections to be applied to the pyrometers under test determined. From the values obtained at the lower temperatures the corrections to be applied at the higher temperatures may be deduced. In a works employing several optical or radiation pyrometers it is advisable to have a standard instrument with which the works' instruments are compared at intervals. The standard instrument should be compared with the standards of the National Physical Laboratory at intervals. In the case of an optical pyrometer, if a "black-body" furnace is not available, a useful test may be made by sighting the instrument under test and the sub-standard on a frosted incandescent lamp. If the current through the lamp is varied a series of readings will be obtained which will show if the scales of the two pyrometers agree, although the readings are not true temperatures owing to the fact that the conditions are so far removed from that of a "black-body."

In conclusion, I would like to urge once again that the only way to maintain a successful pyrometer installation is to make it definitely someone's business to look after the instruments.

A little care daily, will, not improbably, keep an installation in running order. Persuade the fireman or tool maker that the instruments have been installed to help him turn out good work, and he will do his best to take care of the pyrometers in the furnace. Tell him that if he has had the misfortune to knock the couple, either when putting it in or out, or when it is in position, to let you know at once. In pyrometry, as in other matters in life, "a stitch in time may save nine," and the substitution of a new porcelain or quartz sheath for a broken one, will not improbably save the thermocouple and a good deal of worry, if not money.

Keep the leads and switches between the pyrometer and indicator or recorder clean, and in good order. In the case of these instruments take every precaution to protect them from overheating and dust. Having done this there should be little trouble with the pyrometer installation. Too much, however, must not be expected from the installation. It seems unnecessary to expect to read an instrument to one or two degrees when the temperature of the furnace which is being recorded cannot be controlled to within 10 or 20 degrees.

As in all machine tool operations, high accuracy can only be obtained by care, and it is always wise to determine the accuracy required before putting in the installation. The type of instruments used, the sub-standards required, all hang upon this decision which in the majority of cases can be based upon the experience gained by other workers. In many cases the pyrometer manufacturer may be able to advise from his experience gained on similar problems.

I have to thank Mr. W. H. Apthorpe and Mr. F. Price for many useful suggestions.

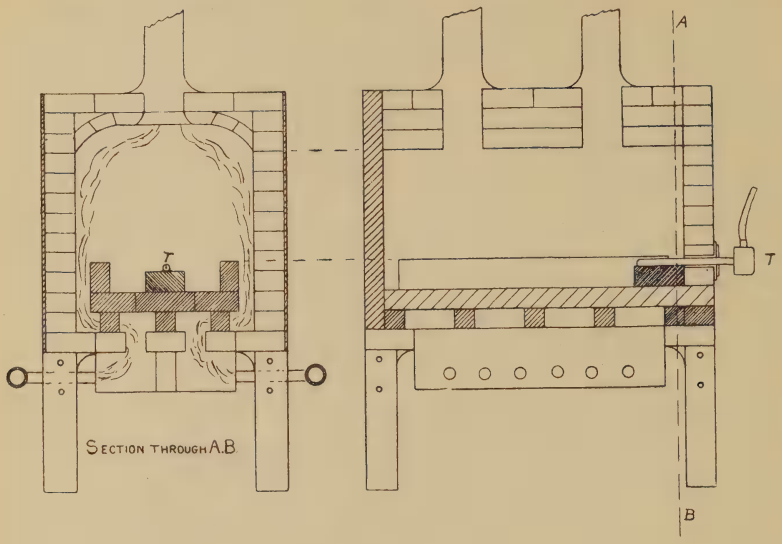


Fig. 1.
Small hardening furnace.
Petit four de trempe.

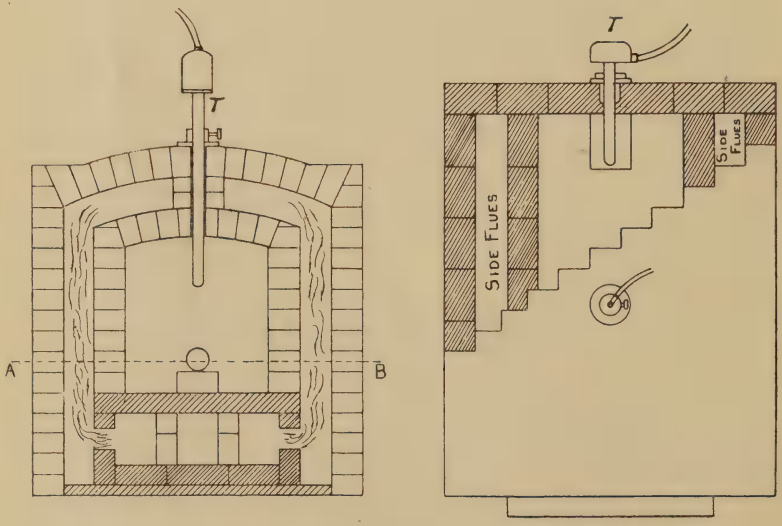


Fig 2.
Re-heating and carbonising furnace.
Four de réchauffage et de cémentation.

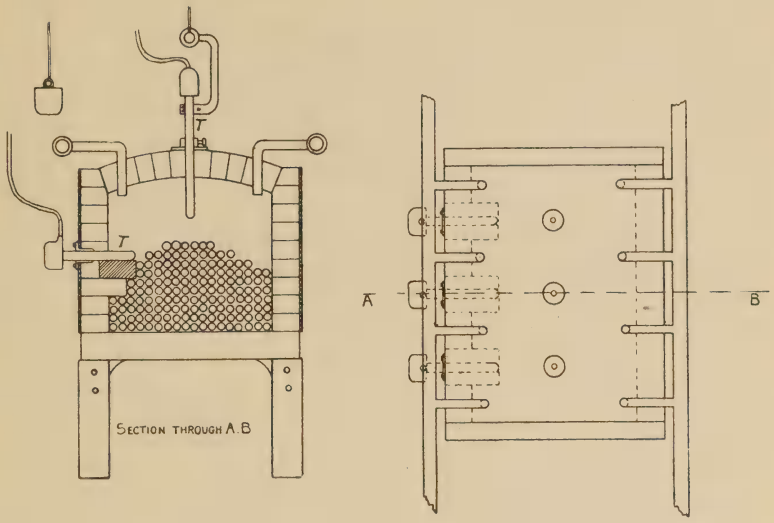


Fig. 3.
Rod annealing furnace.
Four à recuire les barres.

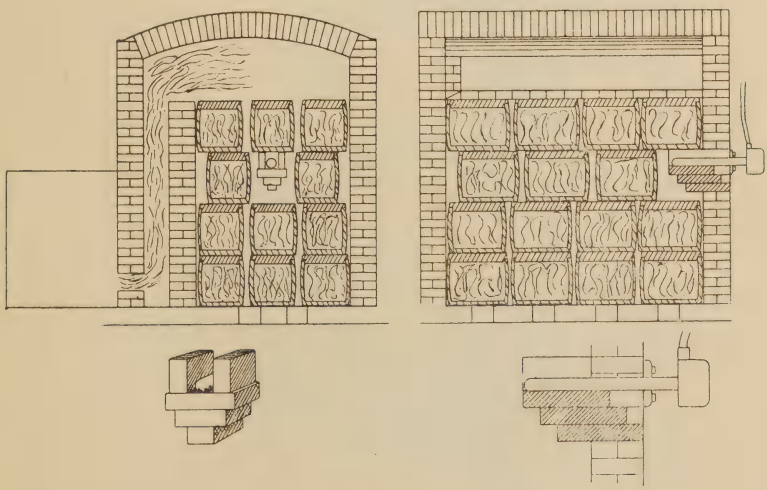
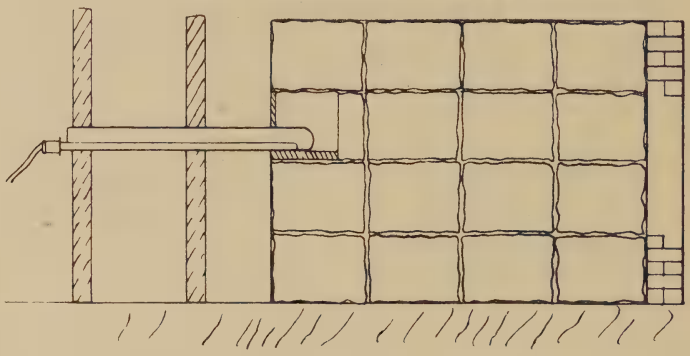


Fig. 4.
Malleable iron pot furnace.
Four avec boîtes pour fonte malléable.



Pottery Kiln—early stage, thermo-couple in use.
Four à poterie—première période, emploi du thermo-couple.

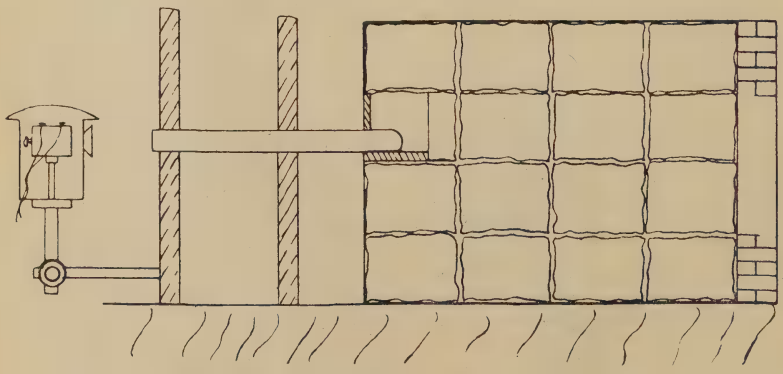


Fig 5.

Pottery Kiln—later stage, radiation pyrometer in use.
Four à poterie—dernière période, emploi du pyromètre à radiation.

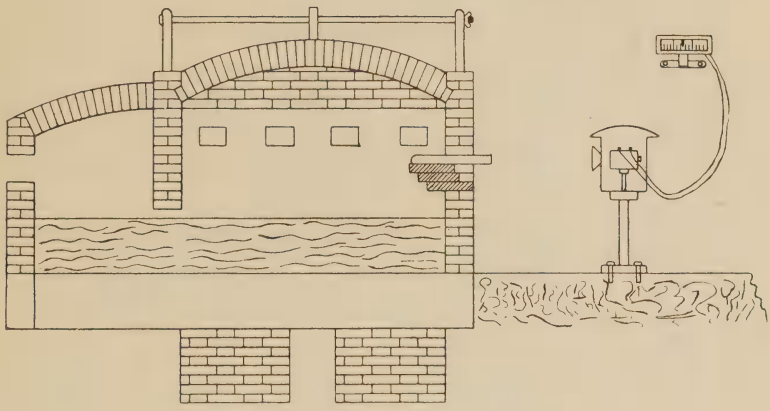


Fig. 6.
Glass-melting furnace.
Four de fusion du verre.

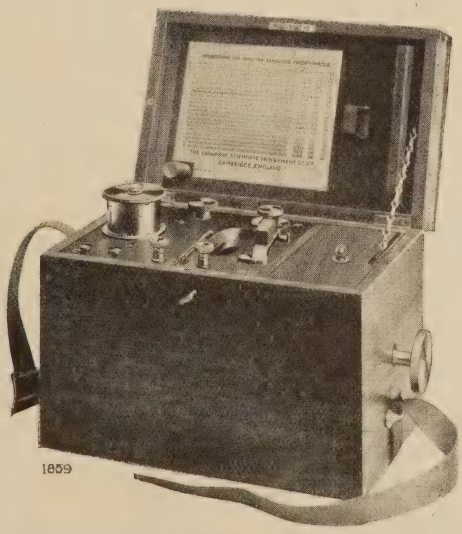


Fig 7.
Portable Workshop Potentiometer.
Potentiomètre portatif d'atelier.

I.—Aperçu de quelques Difficultés Constatées en Utilisant une Installation Pyrométrique dans une Usine.

Par Robert S. Whipple.

LE prix élevé des matériaux et de la main d'oeuvre nous fait sentir de plus en plus le besoin d'avoir un contrôle effectif de la température. Beaucoup de firmes ont maintenant installé des pyromètres dans leurs usines mais il est douteux que la majorité d'entre elles obtiennent de leurs instruments le rendement maximum d'utilisation.

Il est donc intéressant d'essayer de voir quelles sont les difficultés principales constatées dans le maintien en service d'une installation pyrométrique, et les méthodes au moyen desquelles ces difficultés peuvent être évitées ou surmontées.

Avant tout, je suppose que quelqu'un dans l'usine s'occupe spécialement de la bonne marche de l'installation pyrométrique et que cette personne comprend les principes sur lesquels reposent les instruments. L'expérience démontre que les machine-outils ne peuvent fonctionner d'une manière efficace, si personne ne s'en occupe particulièrement. La direction choisit les outils, le contremaître décide de la vitesse à laquelle on doit opérer, mais c'est finalement l'ouvrier qui fait donner à la machine son rendement ou non, en prenant soin que ses burins soient bien affûtés, que la pièce soit correctement montée, et que toutes les autres petites précautions sont prises grâce à quoi, en définitive, les machines seront efficaces. Nous pouvons raisonner par analogie à propos de l'installation pyrométrique, et les raisons pour lesquelles cette installation n'opère pas avec succès peuvent, je pense, être résumées comme suit :

1. Le type d'instrument installé n'est pas convenable.
2. L'instrument n'est pas bien utilisé, ou
3. L'instrument a besoin d'un réglage ou d'une correction.

Presque toutes les difficultés constatées dans l'emploi des pyromètres peuvent être classées dans l'une ou l'autre de ces trois catégories.

A ce point de vue, nous ne nous occuperons pas seulement des difficultés rencontrées dans l'industrie de la céramique et nous examinerons comment elles touchent le plus grand nombre de ceux qui emploient les pyromètres.

1. *Type d'instrument non convenable.*

Il est, à mon sens, décourageant de penser que la personne qui s'occupe des pyromètres a déjà choisi son instrument, et je supposerai qu'elle est encore libre de faire son choix parmi les différents types actuellement sur le marché.

Il est toujours ennuyeux de jeter un outil avant qu'il soit usé, cependant, l'expérience a montré qu'il vaut mieux remplacer un outil inefficace, et en pyrométrie ce principe est le même. Si l'on a choisi un type d'instrument non convenable, on aura avantage à l'abandonner et à le remplacer par un autre qui convienne mieux au travail. En supposant que l'instrument abandonné est toutefois de bonne fabrication, on pourra toujours l'employer quelque part dans l'usine pour un travail qui lui conviendra. Comme pour une machine-outil, le technicien peut donner d'utiles conseils à l'acheteur. Il y a maintenant un grand nombre d'ingénieurs expérimentés dans le traitement thermique des matériaux qui peuvent donner leurs conseils sur le meilleur type d'instrument pour résoudre un problème particulier.

Quand il désire faire une installation, l'acheteur doit tout d'abord réfléchir à la précison avec laquelle il doit faire ses mesures de température, et ensuite décider si les températures doivent être enregistrées d'une façon continue ou seulement indiquées. Avant de prendre une décision, il est important de considérer la valeur et le genre de pièces qui auront à être chauffées dans le four.

Dans le plus grand nombre de cas, le coût initial d'une installation pyrométrique est petit, si on le compare à celui du four et des pièces chauffées dans le four pendant un mois. C'est là une question encore plus importante quand il s'agit d'un grand four rempli de cazettes contenant des objets, ou d'un four à recuire chargé de barres en acier rapide.

L'expérience démontre que, dans la majorité des cas, il est préférable d'installer un enregistreur, spécialement quand il est essentiel que la température, à un moment donné, ne tombe pas au dessous d'une certaine valeur, ou quand le degré de chauffage ou de refroidissement est important.

Après avoir décidé si l'enregistrement de la température doit être continu ou non, l'on doit envisager la position des instruments. Il est naturel que le Directeur tienne à avoir l'enregistreur dans son propre bureau, mais s'il n'est possible d'installer qu'un seul instrument, je pense que cet instrument ne serait pas là à la bonne place. Il devra être placé dans une position telle que le chauffeur, qui s'occupe du chargement du four, puisse voir les enregistrements sans avoir à se déplacer à une distance appréciable de son travail.

Quand l'instrument est à la portée du chauffeur, il le regarde souvent comme un ami qui est là pour l'aider, tandis que si cet instrument est placé dans le bureau du directeur, il le considèrera comme un agent de police qui lui rappelle de ne pas faillir à son devoir.

C'est là une importante différence dans le point de vue de l'ouvrier, et le succès d'une installation pyrométrique dépend de la façon dont le chauffeur considère l'instrument tout comme le succès d'une machine-outil depend de la bonne volonté ou non de l'ouvrier qui l'emploie. Le meilleur moyen est d'installer parallèlement deux instruments, un enregistreur dans le bureau du

directeur et un indicateur dans le local où se trouve le four. Le pyromètre enregistre continuellement, sauf quand le chauffeur introduit l'indicateur dans le circuit au moyen d'un interrupteur-inverseur. Le circuit de l'enregistreur est interrompu pendant quelques secondes alors que le chauffeur lit la température sur l'indicateur. Immédiatement après que l'interrupteur est libéré le pyromètre est de nouveau connecté à l'enregistreur. Quand on se sert d'instruments à haute résistance, l'indicateur et l'enregistreur peuvent être montés en paralléle et employés continuellement, mais ils devront être calibrés quand il y aura des conditions particulières (longueur des fils, etc.) dans lesquelles ils devront être employés.

Il faudra ensuite choisir le genre de pyromètre, et la decision ne peut être prise qu'après un examen attentif des températures à mesurer, ainsi que du degré de précision avec lequel elles devront être mesurées.

Comme guide pour cette selection, les types le plus généralement employés sont les suivants :

Pour les températures variant des

−200° à 700°C.	Le thermomètre à résistance.
0° à 1200°C.	Le pyromètre thermo-électrique.
700° à 2000°C. (ou au-dessus),	Le pyromètre optique ou le pyromètre à radiation.

On voit que les differents types ont des échelles qui chevauchent de sorte qu'on a un choix considérable. Les thermomètres à résistance peuvent être arrangés de façon à avoir une graduation développé sur toute l'échelle des températures, et ils sont employés comme étalons. Les pyromètres thermo-électriques sont très employés, et grâce aux diverses améliorations apportées en ces dernières années, ils sont devenus des instruments de précision, même dans les ateliers. Le pyromètre optique et le pyromètre à radiation ont le grand avantage de ne pas avoir besoin d'être introduits dans la source de chaleur, et en prenant diverses précautions, la température d'un corps chaud peut être mesurée par la luminosité de ce corps ou par la radiation qu'il émet.

Comme régle générale, on peut dire que, dans les ateliers, pour les mesures de températures entre 300°C. et 1200°C., le pyromètre thermo-électrique devrait être employé. Pour un travail demandant une haute prècision, à des températures variant entre 800° et 1200°C., on devra alors se servir de thermo-couples constitués par des métaux du groupe du platine. L'expérience a montré que le couple, platine—platine-rhodié, est le plus satisfaisant et peut être employé pour des températures atteignant 1600°C. pendant de courtes périodes.

Il est presque impossible de protéger un couple contre les gaz délétères à cette haute température et c'est pourquoi on recommande de ne pas l'employer au-dessus de 1200°C. pour n'importe quelle durée. Le prix élevé du platine rend le couple platine—platine-

rhodié trés coûteux, et le couple de métaux de base le remplace avantageusement. Les couples de métaux de base employés généralement sont le fer—constantan (constantan=Ni 90,Cu 10) et le nickel-chrome—nickel-aluminium (nickel-chrome=Ni 90, Cr 10; nickel-aluminium, Ni 98 Al 2); on peut les utiliser jusqu'à 1370°C.

Si l'on désire relever continuellement des températures au-dessus de 1000°C. il faut alors employer un pyromètre à radiation. Des lectures directes peuvent être faites au moyen d'un pyromètre à radiation ou d'un pyromètre optique. Si le corps chaud est petit il faut se servir d'un pyromètre optique.

Quand on prend une décision, on doit se rappeler que chaque type particulier d'instrument a des limites dans son emploi. Dans n'importe quel cas, on doit insister sur une exactitude de 0·1% (1°C. à 1000°C.) et une précision de cette sorte ne peut être obtenue qu'en prenant des précautions spéciales. En supposant que le type d'instrument le plus satisfaisant ait été choisi, un grand pas a été fait pour la bonne marche de l'installation.

2. *L'instrument n'est pas employé convenablement.*

Là encore, je supposerai que les instruments n'ont pas été installés, et je suggérerai les précautions, qui, si elles sont adoptées, éviteront sans aucun doute, un grand nombre de difficultés à ceux qui entretiennent les installations pyrométriques. Souvent, la direction a donné beaucoup d'attention au choix du type correct d'appareil, et cependant les resultats obtenus ne justifient pas les soins ni les dépenses. L'installation est évidemment inadéquate. Pourquoi? Les raisons peuvent être probablement dûes aux faits suivants :

1. Destruction des enveloppes protectrices du pyromètre par chauffage excessif, ou cassure mécanique due à un montage incorrect dans le four.

2. Vibration du support portant le galvanomètre de l'indicateur ou de l'enregistreur.

3. Défectuosité dans les fils, ou connexions insuffisantes.

4. Malpropreté.

5. Besoin de réglage de l'indicateur ou de l'enregistreur.

6. Manque de soin dans le maniement des instruments et inattention dans les détails.

Dans l'utilisation des pyromètres il est absolument nécessaire que les tubes protecteurs, tout en étant très solides au point de vue mécanique, puissent résister à de hautes températures. Je me permets de tirer l'attention de ceux qui s'occupent de la fabrication des matériaux réfractaires sur le manque d'une matière avec laquelle les tubes du pyromètre puissent être fabriqués. La porcelaine est encore la matière la plus satisfaisante. Jusqu'au début de la guerre, la meilleure était fabriquée par la Manufacture royale de porcelaine de Berlin. Les Usines royales de porcelaines de Worcester ont créé une matière qui est presque aussi bonne que celle employée par les Allemands et qui est

meilleure au point de vue de la porosité.* Le quartz fondu peut être employé au-dessus de 1000°C. Il est mécaniquement plus resistant que la porcelaine, parce qu'il est possible de fabriquer des tubes plus épais avec cette matière qu'avec la porcelaine. Il supporte également beaucoup mieux les changements rapides de températures que la porcelaine. Malheureusement on ne peut l'employer à des tempèratures au-dessus de 1000°C. car il se dévitrifie lentement, devient cassant, et laisse pénétrer les gaz.

Les tubes faits d'alundum et de salamandre sont utiles comme enveloppes extérieures et secondaires, mais sont trop poreux pour être employés comme tubes protecteurs spécialement s'il s'agit d'un thermo-couple platine.

Les enveloppes en nichrome sont employées avec succès comme tubes protecteurs secondaires dans plusieurs usines. Elles peuvent se rompre dans les enceintes contenant du soufre telles que dans les fours à coke pour la fabrication de la fonte malléable, mais dans les enceintes ne contenant pas de soufre elles peuvent supporter assez longtemps des températures de 1000°C. Le sérieux inconvénient de ces tubes est leur prix et le fait qu'ils sont assez souvent poreux. A l'exception des dernières mentionnées, toutes ces matieres sont fragiles et c'est pourquoi la manière de monter le pyromètre dans le four est très importante. La vie du pyromètre dépend de son montage plus que n'importe quelle autre condition.

Dans un grand nombre de cas, la direction doit se contenter de mesurer des températures relatives plutot qu'absolues pour les matières placées dans le four. Dans beaucoup de cas, cela n'a pas d'importance, et tout ce qu'on désire c'est de répeter certaines températures qui ont précédemment amené des resultats satisfaisants.

Il y a de nombreux types de fours, mais il peut être intéressant de discuter la méthode de montage des pyromètres dans quelques fours les plus typiques afin qu'on soit guidé dans la solution du problème. Pour n'examiner en premier lieu, que les formes de fours les plus simples, nous prendrons comme exemple le petit four de trempe de la figure 1. Ce four est muni de brûleurs Bunsen, brûlant du gaz à la pression normale. Dans cet exemple, le four a deux orifices d'évacuation des gaz brûlés dans lesquels sont placés des registres. Il n'est pas facile d'introduire un pyromètre à travers la voûte, mais on fait un trou dans le fond du four et le pyromètre repose sur une brique placée sur la sole de ce four; on le protège ainsi contre une rupture. En général, on visse une bride avec une semelle sur la sole en fer qui protège le four de façon à tenir le pyromètre en position. Tres fréquemment un tube en terre réfractaire est fixé à la semelle de façon que le pyromètre puisse être glissé dans la gaine protectrice secondaire, l'élément sensible du

* D'excellent tubes de porcelaine sont maintenant fabriqués par une manufacture japonaise et quelques manufactures américaines.

pyromètre etant protégé par un tube en quartz. De cette façon, le pyromètre est doublement protégé. Il est important de vérifier que la brique réfractaire sur laquelle repose le pyromètre entoure le tube en terre réfractaire. Si cette précaution est prise, et si rien n'est placé sur le pyromètre celui-ci durera pendant plusieurs années, en admettant que la température n'excède jamais 900°C.

Le problème, dans le cas des grands fours à rechauffer et à cémenter comme celui de la figure 2, est beaucoup plus difficile à cause du carneau qui passe au dessus de la voûte du moufle. Le pyromètre doit être placé soit à travers la voûte soit sur le coté.

La figure montre 2 pyromètres placés de ces façons. En ce qui concerne celui passant à travers la voûte, un anneau de briques doit être placé autour du pyromètre dans le carneau, ou si cela ne peut être réalisé, un grand tube en terre réfractaire doit être inséré, à travers la voûte dans l'intérieur du moufle. Bien que des mesures soient prises pour protéger le tube passant à travers le carneau, des difficultés peuvent se produire par suite de la dilatation ou de la contraction des deux arches du four.

Pour cette raison, il est bon, lorsque c'est possible, de disposer le pyromètre à travers la paroi arrière du four. D'un autre côté, si le pyromètre est placé à travers la voûte, on peut, probablement, l'amener plus près des piéces chauffées, et il indiquera la température moyenne du four avec plus de précision. Le traitement thermique correct des alliages d'aciers coûteux est de grande importance, non seulement au point de vue de la dépense mais aussi au point de vue des résultats mécaniques qui doivent être obtenus de la matière traitée. C'est pourquoi il est important d'amener le pyromètre le plus près possible des pièces, et lorsqu'il s'agit de longs fours, il est nécessaire d'employer deux ou trois pyromètres dans le four. Quand les pyromètres doivent être enlevés fréquemment du four, il est important de les protéger par des enveloppes extérieures en acier.

Dans la figure 3, le pyromètre est représenté avec un dispositif de levage qui permet de le sortir facilement du four.

A ce sujet, il est particulièrement recommandé de vérifier avec attention la distribution de la température dans le four avant de s'en servir. Il n'est pas rare de trouver des différences de 30°C. entre la paroi avant et la paroi arrière du four. Dans un tel cas, on ne peut pas s'attendre à un bon travail de la part de l'opérateur, à moins qu'il ne connaisse la distribution de température, en la déterminant au moyen d'un pyromètre placé en différents points. Connaissant la température, la pièce peut être placée en conséquence, les pièces lourdes dans les parties chaudes, et les moins lourdes dans les positions plus froides du four.

L'un des types de fours les plus difficiles pour l'installation d'un pyromètre, est celui employé pour la fabrication de la fonte malléable. Les pièces de fonte sont placées dans des boites en fer qui sont empilées dans le four.

Le chargement et le déchargement du four, qui sont le plus souvent effectués par des ouvriers, rend obligatoire une protection mécanique efficace pour le pyromètre. L'expérience a montré que le pyromètre est mieux supporté lorsqu'il est placé sur des briques en terre réfractaires disposées sur le côté du four comme l'indique la figure 4.

Dans un four à poterie, le problème diffère de celui des autres exemples en ce que deux différents types de pyromètres doivent être employés pour couvrir l'echelle complète des températures. Le contrôle de la température, au début des opérations correspondant au séchage, est important, et un thermo-couple est généralement employé pour cette periode ; dans les dernières periodes du chauffage, on emploie un pyromètre à radiation. Il est d'usage d'introduire dans le four un tube fermé en terre réfractaire ou un tube en silice fondue d'environ 125 mm. de diamètre interne et des metre 200 de longueur (voir figure 5). Dans beaucoup de cas, ce tube est disposé dans la porte du four, et l'extrémité qui est fermée repose sur un morceau de cazette en dedans du four, afin que, autant que possible, la température enregistrée soit celle à laquelle les objets, qui se trouvent dans les cazettes, sont exposés.† Au commencement des opérations, un thermo-couple est introduit dans le tube fermé, et à la fin, lorsqu'on a atteint 700 C., un pyromètre à radiation vise la partie inférieure du tube.

Le contrôle de la température d'un four pour la fusion du verre est de grande importance. La température du verre en fusion (environ 1500°C.) est si élevée et son action est si destructive pour la majorité des matiéres, qu'il n'est pas commercialement possible d'introduire des pyromètres dans le verre. De bonnes lectures comparatives peuvent cependant être obtenues par l'insertion d'un tube de silice fermé dans le four, comme montré dans la figure 6. On aperçoit un pyromètre à radiation Féry visant le fond de ce tube et les lectures obtenues sont très rapprochées de celles du verre en fusion. On admet que les lectures ne sont que relatives, mais l'expérience démontre qu'elles sont de grand service. Si un pyromètre doit résister à des températures extrêmement élevées il doit être monté verticalement à travers la voûte du four ou supporté horizontalement d'un bout à l'autre de toute sa longueur.

S'il passe à travers un tuyau et est soumis à des hautes températures sur toute sa longueur, il est utile d'employer un couple de platine-platine-rhodié. Beaucoup d'ennuis et de dépenses seront évités en agissant ainsi. Si les températures sont hautes et qu'il ne soit pas possible d'employer un pyromètre à radiation, il vaut mieux alors disposer un pyromètre dans une place (si une telle place peut être trouvée) où la chaleur n'est pas si grande que dans

† Voir " Pyrometry as applied to the making of Pottery " (Pyrométrie, comme on l'applique á la fabrication de la poterie) par R. S. Whipple. TRANS. *Eng. Cer. Soc.*, **12**, 202, 1913.

la partie principale du four, et travailler avec des températures comparatives. Il est heureux que, dans presque chaque cas, il soit possible d'employer des pyromètres d'un type ou d'un autre pour l'enregistrement continuel de tous les procédés de traitements thermiques industriels prolongés. La détermination des températures de fusion et de coulée des métaux et de leurs alliages est un problème plus difficile, et on a encore besoin de faire des expériences, pour mettre ce problème sur un pièd satisfaisant.

2. En supposant que le pyromètre soit installé, son montage demande de l'attention. S'il n'y a pas trop de malpropreté ou de vibrations, l'instrument devra, comme mentionné précedemment, être placé le plus près possible de l'ouvrier qui conduit les fours. Les vibrations, sont rarement importantes dans une fabrique, spécialement si l'appareil est dans une position verticale. L'aiguille du galvanomètre peut osciller de haut en bas mais s'il n'y a pas de sérieux mouvement horizontal, les lectures obtenues ne sont pas affectées. En même temps il faut prendre soin que la bobine oscille librement. Dans le cas d'un instrument suspendu, il peut être necessaire de faire la nivellement de l'appareil car la bobine peut toucher les pôles de l'aimant.

3. Les connections défectueuses dans les circuits électriques produisent les plus trompeuses erreurs. Quel que soit le type de thermomètre électrique qu'on emploie, un contact intermittent, ou une résistance qui varie, introduit toujours une erreur et quelquefois d'une mannière très importante. L'instrument peut, en apparence, opérer d'une manière satisfaisante, tandis qu'en réalité il marque une température beaucoup plus basse que celle qui existe. Pour cette raison la connection des fils aux instruments et aux pyromètres doit être faite dans des boîtes de jonction. Tous les interrupteurs doivent avoir de bonnes surfaces de contact et être de bonne qualité. En aucun cas, le proverbe "il ne faut pas gâter l'omelette pour un œuf" ne peut être un exemple plus frappant, que dans le cas d'une installation pyrométrique qui est détériorée à cause d'un manque de fils convenables, ou d'interrupteurs de qualité inférieure.

4. La malpropreté est le grand ennemi des instruments à radiation, et on ne prendra jamais trop de soin pour éviter que la boîte de l'enregistreur se salisse le moins possible. Dans une forge, la poussière est souvent magnétique et les particules de fer qui entrent dans la boîte de l'enregistreur adhèrent aux pôles de l'aimant, empèchant ainsi le libre mouvement de la bobine du galvanomètre. C'est pourquoi il est bon de monter les enregistreurs dans une boîte protectrice extérieure ou armoire, s'il doivent être placés dans un endroit poussiéreux.

5. *L'instrument lui même a besoin d'un réglage ou d'une correction.* J'ai, jusqu'à present, discuté le choix des types d'instruments

qui doivent être employés ainsi que leur installations, mais je n'ai pas parlé de la question des corrections à faire, ou, en d'autres termes, des précautions scientifiques à prendre pour que les lectures des instruments soient correctes. L'étalon final de toute la thermométrie est le thermomètre à gaz, rempli, si possible, d'un gaz" parfait," mais, à présent, le dernier type est le thermomètre à gaz du Bureau international des Poids et Mesures de Sèvres, et c'est à ce type que toutes les mesures des thermomètres doivent être finalement rapportées. Les échelles thermo-électriques des instruments des divers Laboratoires nationaux de Physique sont connues par rapport aux instruments de Sèvres, et c'est avec ces types que les types auxiliaires sont finalement comparés.

Il est intéressant de noter que la détermination des points d'ebullition et de fusion des métaux purs et des autres substances, est devenue la méthode la plus précise pour comparer les types thermométriques variés du monde entier. Dans une usine possédant un laboratoire, on a des facilités pour soumettre aux essais les appareils thermométriques ; n'importe quel nouvel instrument sera naturellement mis à l'épreuve dans le laboratoire avant d'aller dans l'atelier. Il peut être utile d'examiner l'équipement d'un tel laboratoire, en supposant que l'appareillage est employé pour l'essai des instruments de travail plutôt que pour des recherches de laboratoire. Dans un grand laboratoire, les instruments de recherches seront incontestablement employés pour éprouver les étalons secondaires auxquels les instruments de l'atelier seront comparés. Dans un petit laboratoire, les étalons peuvent consister en étalons secondaires, comme dans le grand laboratoire. Dans les deux cas, il est bon que les étalons soient envoyés au Laboratoire national de Physique.

Le fabricant d'instruments de premier ordre est heureux que ceux-ci soient eprouvés par le Laboratoire national de Physique, car il sait que ces épreuves le mettront à même de maintenir un haut degré de précision dans sa propre usine, et qu'une erreur qui pourrait se glisser dans son propre appareil d'étalonnage serait vite découverte. Les sous-étalons ayant été éprouvés au Laboratoire, la personne qui s'en sert sait que son système thermo-électrique peut être lié à l'échelle de température acceptée. L'importance de ce fait est évidente. Un industriel achète de l'acier special americain à un fabricant qui spécifie un traitement thermique defini. L'acheteur sait que si le fabricant déclare que l'acier doit être recuit à une température donnée, il sera à même de reproduire cette température en Angleterre, bien que le fabricant ait mesuré ses températures avec un pyromètre construit aux Etats Unis dont les lectures dépendent des valeurs données par le Bureau des Etalons à Washington.

Dans un grand laboratoire, il est bon d'avoir un potentiomètre précis, une bobine mobile de galvanomètre, une pile étalon et deux ou trois thermo-couples étalon de platine-platine-rhodié.

En plus de ces instruments, il est bon d'avoir un potentiomètre d'atelier contenant un galvanomètre portatif et une pile au cadmium, qui pourront être facilement transportés dans l'usine, et qui représentent des sous-étalons. Dans le laboratoire d'une petite usine, cet instrument peut servir d'étalon.

Si la dépense n'est pas une question importante, il est bon d'avoir un thermomètre à résistance avec un pont ou un indicateur pour contrôler les points plus bas des températures de 0 à 800°C. L'avantage est que la graduation est ample et que l'instrument a un haut degré de précision. S'il n'est pas facile d'envoyer les étalons au Laboratoire national de Physique pour leur vérification, ils pourront être controlés en déterminant les points d'ebullition ou de fusion de diverses substances. Il y a une petite difficulté en déterminant les deux points fondamentaux de l'échelle de température, qui sont le point d'ebullition et celui de congélation de l'eau ; le second est determiné en plaçant un thermomètre dans des morceaux de glace placés dans un vase à double paroi, ou dans un thermoflacon, et le premier point est determiné en mettant le thermomètre dans un simple hypsomètre à vapeur. Quand on relève le point d'ebullition, il ne faut pas oublier que le point d'ebullition de l'eau varie avec la pression barométrique. Pour de plus hautes températures, il est bon d'employer les points de solidification des métaux purs ou des alliages entectiques, et les points des solidification de sels purs. On trouvera utiles et satisfaisants les points suivants:

Point de solidification de l'étain	231·8°C.
,, ,, ,, du plomb	327·4°C.
,, ,, ,, du zinc	419·4°C.‡
,, d'ébullition du soufre	444·7°C.
,, de solidification de l'antimoine	630·7°C.
,, ,, ,, du chlorure de sodium	800°C.*
,, ,, ,, de l'argent	960·8°C.
,, ,, ,, du cuivre	1083·0°C.

Si, pour de hautes températures, on a besoin de pyromètres optiques à radiation, il est utile d'installer un petit mouffle à gaz ou un four à tube électrique pour le contrôle de ces instruments.

Si l'on admet que le laboratoire est équipé, il est utile d'examiner les erreurs qui peuvent se produire dans les travaux. A l'exception des thermomètres en verre au mercure, il est hors de doute que les thermomètres thermo-électriques sont les plus généralement employés dans une usine et les erreurs qui se produisent le plus souvent dans ces thermomètres doivent être examinées. La majorité d'entre elles peuvent être classées comme suit:

‡ Le point de solidification du zinc est un point particulièrement utile; on a constaté que des déterminations faites sur un échantillon de zinc employé continuellement pendant six ans donnaient des résultats strictement concordants.

* Le point de solidification du sel commun (NaCl) à 800°C. est un point extrémement commode car de petites variations dans la pureté de la matière n'ont pratiquement aucun influence sur le point de solidification. Le sel est très volatil à cette tempèrature et peut etre manipulé dans un creuset au fer. Les fumées sont déplaisantes et les essais doivent être faits dans un local bien ventilé.

1. Erreur dûe au changement graduel de la force électromotrice du couple.
2. Erreur dûe à la température inconnue ou incertaine de la soudure froide.
3. Erreur dûe à la résistance des fils ou des connections défectueuses.
4. Erreur dûe à la température de l'indicateur ou au changement dans le galvanomètre lui même.

1. En supposant que le couple est fait de fils bien recuits et de choix, une petite difficulté sera éprouvée dans un travail industriel par suite d'un changement dans les constantes du couple lui même. La force électro-motrice de presque tous les thermo-couples employés, reste remarquablement constante après un chauffage prolongé, même dans les cas ou l'élément est devenu très oxydé. La force électromotrice du couple platine—platine-iridié baisse légèrement après une exposition prolongée à environ 1100°C. à cause de la volatilisation de l'iridium qui contamine le fil de platine pur du couple. Pour cette raison, le couple platine—platine-rhodié a presque complétement remplacé celui à l'iridium. Lorsque c'est possible, il est utile de protéger le thermo-couple (quelles que soient les matières avec lesquelles il a été construit) contre l'oxydation et l'action des gaz des fours. Comme expliqué précédemment, de la porcelaine vermissée ou du quartz seront employés pour cet usage.

2. L'erreur la plus sérieuse rencontrée dans la pyromètrie thermo-électrique est sans aucun doute celle dûe a l'incertitude des températures de la soudure froide. La force électromotrice résultante produite par un couple dépend de la différence de température entre les soudures chaudes et froides. Dans l'étalonnage original du couple, la soudure froide est maintenue à une température constante (le plus souvent à 0°C.) et la soudure chaude est chauffée à de certaines températures définies. La force électromotrice produite à ces températures a été mesurée, et de là, les constantes du couple ont été déterminées. Il est essentiel, quand on mesure la température d'une soudure chaude d'un couple par celle de la mesure de la force électromotrice produite, que la température de la soudure froide soit connue. On suppose que le galvanomètre auquel le thermo-couple est relié, est placé dans un entroit qui n'est pas chauffé d'une manière anormale, ni sujet à de grandes variations de température. La température du galvanomètre est alors considérée comme celle de la soudure froide. Par suite du prix élevé du métal du couple et quelquefois de sa haute résistance spécifique, il n'est pas possible de relier directement plusieurs pyromètres aux galvanomètres avec les mêmes métaux dont sont faits les couples, et l'on a essayé, pour cet usage, des fils de différents alliages.

Dans le cas du thermo-couple de platine, la matière la plus satisfaisante est celle inventée par Peake dans laquelle un alliage

relativement bon marché en cuivre-nickel fournit la même force électromotrice que le couple platine—platine-rhodié.† Dans le cas de quelques thermo-couples de métaux de base d'autres alliages ont été employés comme fils de compensation. Si l'on se sert de fils de compensation, le point ou ils se terminent devient alors la jonction froide du circuit du pyromètre. Si l'on désire obtenir une haute précision, la température de ce point doit alors être contrôlée. La manière d'opérer la plus simple consiste à employer un flaçon à vide rempli d'huile et dans lequel la soudure froide du thermocouple ou des fils de compensation est placée, le point auquel les fils de cuivre rejoignent le couple étant placé pres du fond du flaçon. En pratique, on a constaté que la température de l'air ambiant peut changer de 20°C. en 24 heures, alors que la température dans le flaçon reste constante à 1°C. près. Une autre manière effective de contrôler la température de la soudure froide, est de placer la soudure à une profondeur de 3 metres à 3 m. 60 au-dessous du sol du bâtiment. C'est une méthode simple mais efficace pour maintenir la température constante de la soudure froide à environ 1 ou 2°C. près, pendant toute l'année.

Quand, au début on installe le galvanomètre, le zéro de l'aiguille doit être réglé à la température de la salle. Le circuit du pyromètre est interrompu soit en détachant un fil d'une des bornes, soit au moyen d'un interrupteur établi à cet effet. La température des instruments est déterminée au moyen d'un thermomètre à mercure placé au-dessus et l'aiguille de l'instrument réglée à cette température par la rotation d'une vis de réglage. Il est recommandable de régler le zéro de cette manière quand on veut obtenir des mesures très précises. Quelques fabricants ne marquent pas le zéro sur leurs instruments, mais les calibrent à une température de 20°C. Dans de tels cas, une petite correction est nécessaire si la température de l'instrument est au-dessus ou au-dessous de 20°C.

3. Quand un galvanomètre est calibré pour être employé avec un thermo-couple, on suppose qu'une resistance définie est dans le circuit, et il est essentiel que la même résistance soit approximativement maintenue en pratique. La relation entre la résistance du thermo-couple et de ses fils, et celle du galvanomètre, a été, pendant quelques années, une question épineuse. Si le thermo-couple lui-même est long et de haute résistance, et si sa longueur est soumise à une variation dans le chauffage, la relation entre sa résistance et celle du reste du circuit a de l'importance. Dans un tel cas, le galvanomètre doit avoir une haute résistance, afin que les variations dans la résistance du circuit ne modifient que dans une petite proportion la résistance totale du circuit. Quand un pyromètre à faible résistance est employé, on devrait faire connaitre

† L'invention des cordons compensateurs est dûe à Bristol, mais l'introduction des conducteurs à basse résistance en cuivre nickel est dûe à W. H. Peake.

au fabricant la résistance approximative du circuit complet, afin qu'il puisse calibrer le pyromètre en conséquence.

4. En plus du fait qu'il est largement indépendant de la résistance du circuit, un galvanomètre à haute résistance a l'avantage que ses constantes ne sont pas pratiquement affectées par sa propre température. Prenant un cas typique où la résistance de la bobine mobile est 60 ohms et la résistance d'équilibrage en manganin est de 940 ohms, le coefficient de température du galvanomètre est approximativement 0·2% par 1°C., si l'on néglige l'effet de la température sur le ressort de contrôle et sur l'aimant,qui dans les deux cas est petit. D'un autre côte, si l'on emploie un galvanomètre à faible résistance, les forces disponibles sur la bobine elle-même sont plus grandes, et l'instrument peut être plus robuste. En pratique, un compromis a été adopté, et les galvanomètres ayant une résistance totale d'environ 80 ohms pour les métaux rares, et d'environ 300 ohms pour les couples de métaux de base, ont été trouvés les meilleurs, pour un travail général industriel.‡ Pour un travail demandant une haute précision, un galvanomètre à haute résistance de 1000 ohms (cuivre 60 ohms manganin 940 ohms) peut être employé, le fil de résistance formant seulement un petit pourcentage de la résistance totale.

La méthode potentiométrique pour mesurer la force électromotrice élude les difficultés relatives à la résistance des fils, et est, sans aucun doute, la méthode la plus précise pour mesurer les températures avec un couple thermo-électrique. Bien que cette méthode ait été employée depuis quelques années pour un travail scientifique, c'est seulement depuis une période récente qu'elle a été adoptée industriellement. Il y a maintenant en Angleterre et en Amérique plusieurs formes de potentiomètres d'usines au moyen des quels on peut mesurer les températures avec le minimum de peine. La figure 7 représente un instrument contenant un galvanomètre, une pile étalon, et un accumulateur. Les forces électromotrices données par le thermo-couple sont indiquées directement, à 0·0001 volt près sur une échelle graduée de 0 à 90 millivolts. En pratique, on constate qu'une température peut généralement être mesurée en une minute, à partir du moment ou le thermo-couple est branché. Les usines de n'importe quelle importance devraient toujours posséder un potentiomètre pour contrôler les constantes de leurs couples et de leurs galvanomètres. Ce potentiomètre constitue un important sous-étalon et peut servir à voir lequel de deux couples est correct, ou si le galvanomètre est en faute, la lecture étant obtenue sur le potentiomètre en équilibrant la force

‡ L'arreur introduite si un galvanomètre est chauffé au dessus de la température à laquelle il a été calibré, n'est serieuse que si on veut exécuter un travail précis. En effet, si un instrument a une résistance de 300 ohms. (bobine mobile, cuivre, 40 Ohms· résistance d'équilibrage en manganine, 260 ohms , a éte calibré à une température de 15°C et si on l'emploie dans l'atelier à une température de 50°C. l'erreur produite—en supposant que le thermo-couple soit à 700°C—serait de 12°C, c'est-à-dire la température indiquée par l'instrument serait de 688°C au lieu de 700°C.

électromotrice fournie par le couple, par celle produite par une pile étalon. Ce dispositif est pratiquement indépendant des changements qui pourraient se produire dans la sensibilité du galvanomètre du potentiomètre. Cette méthode à l'inconvenient de donner des lectures intermittentes en raison de ce qu'elles ne peuvent être prises que lorsque l'équilibre électrique est obtenu. Pour cet raison, il est douteux que le potentiomètre puisse remplacer l'instrument à lectures directes dans un atelier.

On a fait mention de l'effet de température sur le galvanomètre par suite du coefficient de température de l'instrument, mais en pratique, ce n'est pas le plus sérieux effet de surchauffage de l'instrument. La bobine du galvanomètre est une pièce délicate du mécanisme et peut être facilement déformée par le surchauffage, et cependant il arrive assez fréquemmant que l'instrument travaille continuellement, à des températures de 50 à 70°C. Comme expliqué précédemment des sérieuses erreurs peuvent se produire si le galvanomètre forme la soudure froide du circuit, et pour cette raison il est de toute nécessité que le galvanomètre, particulièrement si c'est un galvanomètre enregistreur, ne soit pas surchauffé. Ceci peut, pour quelques cas, nécessiter l'emploi de longs fils pour relier le pyromètre à l'instrument, mais si l'on se sert de fils de compensation, le désavantage n'est pas sérieux, et l'instrument pourra ainsi se trouver dans une place moins poussiéreuse. Dans le cas de thermomètre à résistance, les mêmes précautions générales, quant à l'insertion du pyromètre dans le four et à l'importance de bonnes connections dans les circuits électriques, sont recommandables. Il y a deux methodes employées généralement pour mesurer la résistance des thermomètres. Dans les deux methodes, la bobine du thermomètre forme un côté d'un pont de Wheatstone, aucun courant ne passe à travers le galvanomètre (qui est placé en travers du pont) quand la bobine du thermomètre est à une température specifiée. Dans la première méthode—celle de déflexion—le galvanomètre dévie quand la température du thermomètre monte ou descend, l'echelle étant divisée directement en degrés de températures. Dans la seconde méthode—méthode d'équilibrage ou "du zero"—la résistance dans l'autre bras du pont varie soit automatiquement, soit à la main, jusqu'à que l'équilibre soit rétabli. La première méthode est généralement celle qui convient le mieux si une graduation relativement serrée n'est pas un obstacle. Dans ce cas, la résistance du thermomètre est elevée, 80 ohms à 0°C., et on n'a pas besoin de fils de compensation. Ceci a l'avantage que, deux connections devant seulement être établies ou interrompues quand on branche ou détache le thermomètre du galvanomètre, la méthode se prête facilement au liage d'un grand nombre de thermomètres par un tableau de distribution à un galvanomètre.*

* Quand un grand nombre de thermomètres doivent avoir leurs indications lues sur un galvanomètre au moyen d'un commutateur, ils sont généralement connectés à un fil de retour commun de sorte qu'une seule connection doit être interrompue.

La méthode étant une méthode de déviation, la valeur de la déviation ne dépend pas seulement de la résistance du thermomètre, mais aussi de celle du circuit. C'est pourquoi il est nécessaire de normaliser le circuit en y réglant le courant au moyen d'un rhéostat. Un autre moyen efficace sur une petite échelle consiste à modifier le flux magnétique dans l'entrefer de l'aimant du galvanomètre au moyen d'un shunt magnétique ; de cette façon, en augmentant le flux magnétique dans l'entrefer de l'aimant, une diminution de la force électromotrice de la batterie peut être compensée. Dans la méthode de déviation, la sensibilité de l'installation doit être vérifiée au moins tous les jours, et si l'on a besoin de beaucoup de lectures, pendant 24 heures, elle doit l'être à de plus fréquents intervalles. Les instruments doivent être disposés d'une manière telle qu'ils puissent être vérifiés sans difficulté.

Dans la méthode du zéro, ces précautions ne sont pas nécessaires. On peut presque assurer que, quand l'appareil opère, il marque les lectures correctement, en supposant, bien entendu, que le thermomètre et ses fils soient en bonnes conditions. Il est seulement nécessaire de veiller à ce que la force électromotrice de la batterie ne tombe pas au-dessous d'une valeur donnée. D'un autre côté, tel qu'il est généralement arrangé, le thermomètre employé dans la méthode du zèro comprend des fils de compensation, et il n'est pas si facile de l'utiliser avec un grand nombre de thermomètres. La méthode du zéro a aussi l'inconvénient que la température ne peut être lue jusqu'a ce que l'équilibrage ait été effectué soit par l'observateur, soit par l'instrument. Dans toutes les mesures avec les thermomètres à résistance, la température des instruments eux-mêmes est de peu d'importance comparativement à celle des instruments employés dans les mesures thermo-électriques. Dans la méthode de déviation, l'instrument est compensé automatiquement quand le calibrage quotidien est fait, et dans la méthode du zéro, l'instrument est pratiquement independant de la température.

Avec les pyromètres dont les lectures dépendent de la quantité de radiation reçue du corps chaud, on a un nouveau groupe de difficultés. Ces pyromètres peuvent être divisés en deux classes : ceux dépendant de la radiation totale émise par le corps chaud et ceux dépendant de la radiation lumineuse. Les premiers se rapportent généralement aux pyromètres à radiation, et les derniers aux pyromètres optiques.

L'intensité de la lumière émise par un corps chaud varie considerablement avec sa température, et c'est pourquoi, à première vue, on pourrait supposer que la façon la plus simple de mesurer une température serait de comparer, photométriquement, la lumière émise par le corps chaud avec celle émise par un second corps chaud à une température définie. Cela serait la manière la plus simple de proceder si tous les corps à la même température émettaient la même quantité de lumière, mais malheureusement cela n'est pas

le cas, la lumière, par exemple, du fer ou du charbon incandescent est beaucoup plus grande que celle de la porcelaine ou du platine à la même température.

Kirchhoff, le premier, émit l'idée d'un "corps noir" qui absorberait toutes les radiations tombant sur lui, et qui n'en refléchirait ni n'en transmettrait aucune. Il a montré que la radiation de ce corps noir est une fonction de la température seule et est identique à la radiation d'un espace clos, dont toutes les parties sont à la même température. On a déja mentionné que le fer, le carbone, etc.....n'émettent pas la même quantité de lumière lorsqu'ils sont chauffés à la même température. Si, cependant, ils sont chauffés dans un corps noir, et les fours industriels ordinaires remplissent pratiquement les conditions du corps noir, ils émettent alors tous la même radiation et si l'on les regarde dans le four à travers une petite ouverture ils apparaissent d'un éclat uniforme. Il est, ainsi, possible avec un four remplissant les conditions du corps noir, de déterminer sa température par l'énergie rayonnée.

Les pyromètres optique et à radiation sont généralement gradués pour donner la vraie température d'un corps quand il est dans les conditions du corps noir, c'est-à-dire quand il est complètement enfermé dans un four dont les murs sont à la même température que le corps. Un pyromètre gradué pour donner la lecture correcte dans les conditions d'un corps noir est souvent appelé pyromètre à lectures de "température d'un corps noir" ce qui veut dire qu'il donne alors la vraie température, tandis que dans d'autres conditions il ne la donnerait pas, les lectures étant trop basses. La différence dépend de la composition du corps chaud et de la valeur dont varient les conditions de l'expérience par rapport à celles d'un vrai corps noir. On a constaté que la température apparente d'une matière quand elle est en dehors des conditions du corps noir, est toujours unie par une relation déterminée à sa vraie température.

Par exemple, la température du corps noir d'un morceau de fer à 1,200°C. sera 1,140°C., et celle de la porcelaine à la même température 1,100°C. Je n'entrerai pas ici dans le côté théorique de la question et renvoie les interessés aux excellents ouvrages publiés sur ce sujet.†

Les premiers pyromètres basés sur la radiation totale émise par un corps chaud, et les plus généralement employés sont ceux de Féry, de Foster et de Thwing. Ils sont tous basés sur le principe que la radiation du four est concentrée, au moyen d'un réflecteur, sur un thermo-couple, et ainsi, la force électromotrice indiquée par le couple varie avec la radiation qu'il reçoit. Il a été établi que la

† Voir "Methods of Measuring Temperature," par Ezer Griffiths—chapitres V et VII chez C. Griffin and Co. "The Measurement of High Temperatures," par G. K. Burgess page 238 chez J. Wiley and Sons
"Pyrometry" par C. R. Darling,—chapitre II, chez. E. & N. Spon, Ltd.
"Practical Thermometry" par E. S. Ferry, G. A. Shook & J. R. Collins; chapitres IV et V chez J. Wiley & Sons.

valeur de radiation varie avec le quatrième puissance de la température. L'observateur doit admettre, quand il reçoit le pyromètre du fabricant (particulièrement si l'instrument a été contrôlé au Laboratoire national de Physique) que l'instrument indique les températures réelles lorsqu'il vise un corps chaud placé dans les conditions du "corps noir." Comme expliqué ci-dessus, le four ordinaire industriel remplit pratiquement ces conditions. Un tube fermé en terre réfractaire ou un tube en quartz disposés dans un four réalisent les conditions les plus idéales. Si en pratique, on peut maintenir ces conditions il n'y a qu'une petite différence dans la température d'un four indiquée par un thermo-couple ou par un pyromètre à radiation. C'est seulement quand ces conditions ne peuvent être maintenues que la difficulté se présente. Si l'on essaye par exemple de prendre la température dans un creuset de métal avec un pyromètre à radiation, la température indiquée diffèrera de la température marquée par un pyromètre plongé dans le métal, la difference entre les deux dépendra du métal particulier dans le creuset et des conditions de l'expérience. Après tout, ceci ne prouve pas que c'est un inconvénient. Dans la majorité des opérations, c'est une question de repétition de conditions déterminées, et si un procédé de fabrication réussit quand on réalise une certaine température apparente, la température exacte est de peu d'importance si ce procédé peut être répété avec succès.

Il faut toujours se rappeler que l'instrument ne peut donner des indications correctes que lorsque certaines conditions sont remplies, et, heureusement, dans la majorité des cas de l'industrie, ces conditions étant remplies, le pyromètre à radiation rend de grands services. Il a l'avantage de pouvoir être installé d'une façon permanente pour indiquer les températures (voir figure 5) et les lectures sont marquées directement sur un cadran ou sur une feuille d'enregistrement, éliminant ainsi l'équation personnelle de l'opérateur. Tant que l'image du corps chaud, formée par le réflecteur concave est suffisamment grande pour couvrir le petit thermo-couple placé dans le thermomètre, l'installation opère indépendamment de sa distance par rapport au corps chaud. C'est simplement une question de calcul, étant donné la forme de l'objet, que de déterminer la distance à laquelle le thermomètre Féry devra être placé‡

‡ La relation entre la dimension du corps chaud et l'image formée par un miroir concave est

$$O = I\left(\frac{u}{f} - 1\right)$$

dans laquelle O est la diamètre du corps chaud, I celui de l'image de ce corps, u la distance du corps chaud au miroir, et f la longueur focale du miroir—Voir "Methods of Measuring Temperature," par Ezer Griffiths, page 91.

Pour un thermomètre modèle Féry, Burgess et Foote annoncent les relations suivantes :

Distance du corps chaud au pyromètre.	*Diamètre du corps chaud.*
70 cm.	1·2 cm.
80 cm.	1·4 cm.
100 cm.	1·8 cm.
150 cm.	3·1 cm.
200 cm.	4·2 cm.
300 cm.	6·3 cm.
500 cm.	10·7 cm.

Quand on fait viser un pyromètre enregistreur Féry, sur le fond d'un tube fermé placé dans un four, il est important de veiller à ce que l'extremité extérieure du tube ne coupe pas la radiation reçue de la partie basse. Le tube ne devra pas avoir un diamètre interne de moins de 10 cm. Il est important de s'occuper de ce que le miroir ne se salisse pas, car son pouvoir réflecteur diminuerait. Dans une installation permanente où il y a beaucoup de poussières dans l'atmosphère on doit préserver les instruments de cet inconvénient. Une vitre est une protection efficace contre la poussière, mais l'instrument ne doit pas être calibré à moins de 3 points au-dessus de l'échelle quand une vitre est installée. Il n'est pas suffisant de le calibrer seulement pour une température, car l'absorption de la chaleur de radiation par la vitre varie pour différentes températures. Un miroir peut être terni considérablement sans que son pouvoir réflecteur des radiations à grandes longueurs d'onde soit affecté, or, la plus grande partie de l'énergie réfléchie est à grandes longueurs d'onde. Les miroirs de pyromètre faits en acier inoxydable sont ceux qui donnent le mieux satisfaction. Ils sont pratiquement incassables et internissables. Étant durs, ils peuvent facilement être polis sans rayures.

Les remarques précédentes ayant trait à l'importance des conditions du "corps noir" sont valables généralement pour les pyromètres optiques, bien qu'elles ne soient pas d'une importance fondamentale comme dans le cas des instruments à totale radiation. Si la température d'un "corps noir" a été déterminée en obtenant que la lampe d'un pyromètre optique et le "corps noir" aient le même éclat apparent quand la lumière d'une certaine longueur d'onde (generalement 0·65 μ) est employée, si le pyromètre est alors dirigé sur un autre corps rayonnant dans les conditions du "corps noir," le rapport de la température des deux corps peut être obtenu. On peut dire que généralement "l'éclat total" d'un corps varie avec la cinquième puissance de sa température.*

Les deux formes communes du pyromètre optique sont le type du "filament disparaissant" et le type "polarisant." Le

* Pour une discussion complète des formules sur les quelles les échelles du pyromètres optiques sont baseés, voir " Methods of Measuring Temperatures " Chapitre 7.

premier fut inventé par Morse et perfectionné par Holborn et Kurlbaum. Il est d'un usage général aux Etats-Unis. L'instrument est un télescope dans lequel l'image d'un corps chaud est mise au point sur une surface plane contenant le filament d'une lampe électrique. Le courant dans la lampe varie jusqu'à ce que le filament disparaisse dans l'image du corps chaud. Un diaphragme en verre rouge est placé au-dessus de l'oculaire pour donner une lumière monochromatique. En employant cet instrument, il faut veiller à ce que les lentilles soient propres et que la lampe ait servi plusieurs fois d'une manière satisfaisante avant d'être employée dans le pyromètre.

En Grande Bretagne et sur le Continent, le type polarisant est très employé. Il consiste en un spectro-photomètre dans lequel un rayon lumineux du four est opposé à un autre qui est obtenu d'une lampe électrique. Le courant à travers la lampe est réglé au moyen d'un rhéostat et d'un ampère-mètre. L'intensité du rayon donné par la lampe est opposée à celle d'une lampe acétate d'amyle, par le réglage d'un courant passant à-travers la lampe. Cela rend la graduation du pyromètre independante de la constance de la lampe électrique. L'observateur a ainsi une méthode toute prête pour contrôler son pyromètre à n'importe quel moment. Il est important de veiller à ce que le petit écran en verre dépolie, employé devant la flamme d'acétate d'amyle pour réaliser un champ d'éclairage uniforme, soit propre.

Pour contrôler un pyromètre optique ou à radiation, on doit employér un four "corps noir." Un four tube chauffé électriquement, ou un petit moufle à gaz peuvent être employés pour des températures de 1200° à 1400°C. suivant le type de four. Un thermo-couple est monté sur la partie antérieure d'un petit bloc de terre réfractaire ou de quartz placé dans le moufle, et le pyromètre vise directement sur le couple ou dans l'ouverture du moufle. La température apparente, indiquée par le pyromètre optique ou à radiation, est alors comparée à celle indiqueé par le thermo-couple pour des valeurs diverses. Les résultats sont alors rapprochés et les corrections sont appliquées aux thermomètres, après une épreuve determinée. On peut déduire des valeurs obtenues à de plus basses températures les corrections qui doivent être apportées à de plus hautes températures. Dans une usine employant plusieurs pyromètres optiques ou à radiation, il est bon d'avoir un instrument étalon auquel les instruments de l'usine seront comparés à divers intervalles. Les instruments servant d'étalons devront, de temps en temps, être comparés à ceux du Laboratoire national de Physique. Dans le cas d'un pyromètre optique, si un four "corps noir" ne peut être employé, on peut vérifier l'instrument en visant avec lui et l'étalon une lampe dépolie à incandescence. En faisant varier le courant dans la lampe une série de lectures sera obtenue et montrera si les graduations des deux pyromètres concordent, bien que les lectures ne soient pas les vraies températures, par suite du

fait que les conditions sont éloignées de celles d'un "corps noir."

Comme conclusion, j'aimerais à insister une fois de plus sur le fait que la seule manière de maintenir en bon état une installation pyrométrique, est de charger quelqu'un de s'occuper spécialement des instruments. Un peu d'attention chaque jour permettra de maintenir sûrement une installation toujours en bon ordre.

Persuadez au chauffeur ou à celui qui fabrique les outils, que les instruments ont été installés pour l'aider à faire du bon travail. Dites lui qui s'il a la malchance de détériorer le couple, quand il le met dans le four ou autrement, de vous en faire part immédiatement. En pyromètrie, comme dans la vie, un ourlet fait à temps en sauve neuf, et le remplacement d'une enveloppe cassée par une nouvelle en porcelaine ou en quartz, économisera non seulement de l'argent, mais évitera beaucoup d'ennuis en ce qui concerne le thermo-couple.

Gardez les fils et les interrupteurs placés entre le pyromètre et et l'enregistreur propres et en bon état. Prenez pour ces instruments toutes les précautions pour les protéger du surchauffage et de la poussière. Ceci fait, il n'y aura que peu d'ennuis avec l'installation pyrométrique.

Il ne faut cependant pas trop exiger de l'installation. Il n'est pas nécessaire de lire un instrument à un ou deux degrés près quand la température de l'instrument qui doit être relevée ne peut pas être controlée à moins de 10 ou 20 degrés.

Comme dans toutes les opérations d'usinage, on ne peut obtenir une haute précision que par le soin, et il est toujours sage de déterminer la précision désirée, avant de faire l'installation. Les types d'instruments employés, ainsi que les sous-types dont on aura besoin, dépendent de cette décision, qui, dans la majorité des cas, peut être basée sur l'expérience acquise par ceux qui s'occupent de ce travail. Dans beaucoup de cas le fabricant de pyromètres peut être à même de donner ses conseils basés sur des problèmes similaires.

Je dois remercier M. W. H. Apthorpe et M. F. Price de leurs nombreuses et utiles suggestions.

II.—Résistance à L'Écrasement des Produits Réfractaires aux Différentes Températures.

Par V. Bodin.

PARMI les caractéristiques des produits réfractaires une des plus utiles à déterminer est *l'aptitude qu'ils ont à supporter la charge aux différentes températures.*

Il est, en effet, fréquent que les maçonneries des fours aient à subir, soit du fait de leur élévation, soit de celui des poids placés d'une façon permanente ou intermittente à leur partie supérieure, des surcharges importantes ; dans les voutes, lorsque les produits employés augmentent de volume, les pressions développées peuvent être considérables.

On s'est longtemps borné, en raison des difficultés expérimentales auxquelles on se heurte lorsqu'on veut opérer à chaud, à déterminer la charge de rupture à la température ordinaire ; or, celle-ci, comme nous le verrons ultérieurement n'a pas de relation avec la charge de rupture aux différentes températures; elle n'apporte donc pratiquemment qu'un renseignement d'un intérêt médiocre à celui qui utilise les matériaux réfractaires.

Il n'est cependant pas mauvais de maintenir dans les conditions de réception une limite inférieure pour cette résistance, à la température ordinaire, afin que les produits présentent une solidité suffisante leur permettant de subir, sans dommages, les chocs des transports, mais cette condition n'implique pas qu'ils auront une bonne résistance aux températures élevées.

La température de fusion ne renseigne pas non plus à ce sujet car malgré l'incertitude qui règne encore sur les températures de ramollissement des différents produits, on peut affirmer que l'écart qui existe entre elle et celle de fusion varie dans des limites très étendues suivant les produits ; très considérable par example pour la bauxite et surtout pour la magnésie il est beaucoup plus restreint pour les produits de silice.

Il était donc naturel que les expérimentateurs recherchassent une méthode pour déterminer directement la charge de rupture à l'écrasement aux différentes températures.

Les premiers essais exécutés en ce sens le furent, si mes recherches sont complètes, par le professeur Gary du Laboratoire de Gross-Lichterfeld. La question lui avait été posée par des constructeurs d'appareils récupérateurs Cowper. Ces appareils, comme l'on sait, sont des cylindres assez élevés dans lesquels on dispose des empilages de briques réfractaires que l'on chauffe en

y faisant passer les gaz brûlés sortant du four et qui servent ensuite à échauffer l'air ou le gaz allant aux bruleurs. Pour des raisons particulières l'élévation des Cowper ayant du être augmentée, le constructeur craignait de voir les produits placés à la base s'écraser au moment où la température serait maxima ; cette température était d'environ 1000°.

Gary imagina un dispositif spécial et détermina comparativement la résistance à l'écrasement à 1000° et à la température ordinaire de plusieurs qualités de briques réfractaires.

Les résultats moyens qu'il obtint furent les suivants :

		Charge de rupture en kg. cm.	
		Temp. ord.	à 1000°C
1°)	Brique rhénane du commerce	169	218
2°)	Brique P.W. 10 ..	148	163

Il crut pouvoir en conclure qu'il n'y avait aucun danger d'écrasement puisque la résistance à 1000° était supérieure à celle à la température ordinaire.

Nous verrons par la suite qu'il n'aurait sans doute pas conservé cette opinion s'il avait opéré à des températures intermédiaires.

Pendant la guerre l'importance des matériaux réfractaires dans les fabrications métallurgiques attira sur eux l'attention des savants expérimentateurs de l'Entente et notamment le Docteur J. W. Mellor en Angleterre et M. Henry le Châtelier en France reprirent la question de la résistance à l'écrasement à chaud des produits réfractaires. M. Henry le Châtelier construisit un appareil et fit un certain nombre d'expériences d'où il déduisit que cette résistance diminuait d'une façon assez régulière avec l'élévation de temperature. Alors Chef du Service des Essais de Matériaux de Construction au Laboratoire d'Essais du Conservatoire National des Arts & Métiers, j'eus l'honneur d'être en rapport avec M. Henry le Châtelier et il me montra son dispositif. Je repris l'idée et pus mettre au point un appareil d'un principe analogue mais j'eus la bonne fortune de pouvoir, avec les collaborateurs que j'avais alors, effectuer un très grand nombre d'expériences.

La plupart des produits essayés me furent remis, à la demande de MM. Ch. Guérineau & Co, par M. A. Bigot qui ne cessa de m'encourager et de m'aider en m'apportant l'appui de son incomparable expérience en toute matière céramique.

Les résultats obtenus me permirent pour chaque produit de tracer une courbe des charges de rupture en kg/cm², en fonction des températures, depuis la température ordinaire jusqu'à 1500°C.

Quelques-unes de ces courbes ont été publiées par M. A. Bigot dans son magistral mémoire sur les "*Produits de silice*" en Angleterre dans "The Transactions of the Ceramic Society" en France dans "Chimie et Industrie" n° de décembre 1918 et reproduit dans "la Céramique" n° d'avril 1919.

Le procédé y est sommairement décrit sous le nom *"Méthode du capitaine V. Bodin."*

Je ne reviendrai pas sur ce qui à été dit, mais j'ajouterai un certain nombre de détails concernant le dispositif d'essai, et aussi des considérations sur les renseignements et les conclusions que l'on peut tirer des résultats, et qui résultent directement de la forme des courbes; je montrerai ensuite que les autres procédés d'essai utilisés ne me paraissent pas permettre d'obtenir des renseignements aussi complets.

Dispositif d'essai. La machine servant à produire les pressions, fig. 2, était la machine de traction des métaux de Frémont. Elle avait été munie d'un appareil de réversion R construit spécialement à cet effet aussi grand que possible et permettant de placer entre ses plateaux un four à flamme spiralée F également construit spécialement pour ces expériences.

Ce four chauffé au gaz et à l'air comprimé est nettement visible sur la figure où il est représenté en coupe, en plan et en élévation. La flamme tourne dans un espace annulaire et le tube central t, ouvert à ses deux extrémités, forme en réalité un véritable mouffle. C'est dans ce tube qu'est placé, entre deux cylindres C_1 et C_2 chargés de transmettre les pressions, l'échantillon E à essayer, taillé en forme de cube de 20 mm. de côté. Le plateau inférieur P_1 de l'appareil de réversion est fixe ; c'est sur lui que repose le cylindre C_1 supportant le cube ; le plateau supérieur P_2 au contraire est mobile; il peut s'abaisser lorsqu'on agit au moyen du volant V commandant les engrenages, sur la vis inférieure, et provoquer ainsi l'écrasement du cube.

La température est indiquée sans cessa au moyen d'un couple Pt.—Pt.-Rh. dont la soudure est amenée au voisinage immédiat du cube et qui est placé pour cela dans un petit tube traversant le four et débouchant d'une part à l'extérieur et d'autre part à l'intérieur du tube central t.

Il y avait une légère difficulté à placer le cube au centre du cylindre C_1 ; on remarqua que malgré les précautions prises il arrivait fréquemment que sa position se trouvait défectueuse; on s'en aperçevait après l'écrasement. Un petit tour de main permit de remédier à cet inconvénient en collant au moyen d'un mastic qui brulait à basse température le cube sur son support.

La machine de Frémont comporter un dispositif enregistreur D ; un chariot A est mobile le long de deux tringles horizontales H ; il est relié par un fil métallique aux deux plateaux et ses déplacements sont proportionnels à ceux de P_2 par rapport à P_1 ; ce chariot porte un cadre vertical B sur lequelle on peut fixer une feuille de papier ; un style S monté sur un levier amplificateur L constitué par un tube léger, permet d'enregistrer pressions développées par la machine ; celles-ci sont en effet proportionnelles aux déformations de la partie M de la machine qui actionne le levier.

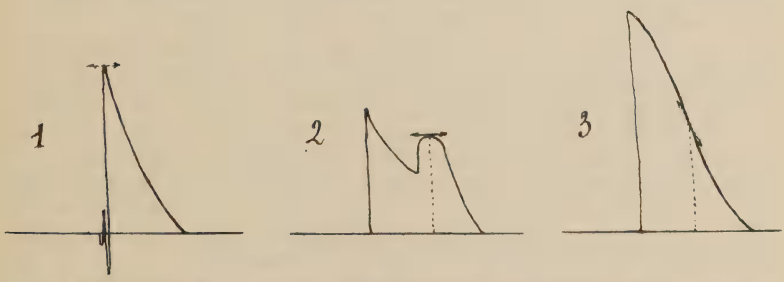
Le chariot coulissait sur les tringles au moyen de 4 douilles ;

pour le rendre plus mobile nous le fîmes monter sur des billes roulant dans deux gorges. Jamais d'ailleurs nous fîmes état de ses déplacements pour mesurer les affaissements de l'échantillon car en raison de l'échauffement inévitable de certaines parties métalliques de la machine et de l'allongement possible du fil on ne pouvait avoir aucune indication sérieuse.

Par contre l'ordonnée du diagramme obtenu permettait, grâce à un tarage préalable de la machine au moyen de sa bascule, de connaître la charge de rupture. La possibilité de relever les diagrammes d'écrasement et d'observer leur forme fut une circonstance des plus favorables, à laquelle on doit en grande partie attribuer la réussite de ces expériences.

Une opération s'éxécute de la façon suivante : On introduit dans le four froid le support inférieur et le cube à essayer, on place le cylindre supérieur, on met le couple en place et on allume le four ; il faut environ une heure pour atteindre 1500°C. Lorsqu'on arrive au voisinage de la température fixée pour l'expérience on règle le four de façon à ralentir très notablement la rapidité de montée de la température et lorsque celle-ci est atteinte, après avoir disposé une feuille de papier dans le châssis de l'appareil enregistreur et réglé le style, on provoque l'écrasement au moyen du volant. Cette dernière partie de l'opération dure moins d'une minute.

On observe alors le diagramme obtenu ; celui-ci suivant les températures et les produits présente 3 formes caractéristiques différentes.



La forme n° I correspond à un écrasement brusque de la matière comme il se produit à la température ordinaire ; généralement c'est cette forme de diagramme que l'on observe jusque vers 1100 au 1200°C.

Pour les températures plus élevées, on a généralement un diagramme de la forme 2 ou 3 ; nous dirons que la forme 2 correspond à l'écrasement d'une matière *semi-plastique* ; c'est généralement le cas des produits silico-alumineux comportant une addition de chamotte ou de quartz ; et que la forme 3 correspond à l'écrasement d'un corps *plastique* ; c'est le cas des argiles pures.

Dans le cas du diagramme n° 2, certains éléments donnent lieu à un écrasement qui provoque la descente, puis la courbe

remonte ; si on poursuit l'opération on peut retrouver plusieurs sommets successifs ; c'est toujours le premier que nous avons pris pour mesurer la charge de rupture ; cette forme qui est une transition entre 1 et 3 peut d'ailleurs présenter des aspects assez différents.

Dans le cas du diagramme n° 3, on n'observe aucune rupture ; la pression monte indéfiniment ; et sans l'enregistrement du diagramme il eut été impossible d'obtenir aucune indication ; celui-ci présente un point d'inflexion et est semblable à celui qu'on obtient quand on écrase un petit cylindre de métal très doux tel que le plomb ou le laiton.

Par analogie et aussi guidé par les autres diagrammes de formes transitoires, on a pris comme charge de rupture, la charge donnée par l'ordonnée du point d'inflexion.

On pouvait se demander si dans ces conditions la durée de l'opération n'influait pas grandement sur la forme du diagramme ; des expériences faites à ce sujet montrèrent qu'on pouvait la faire varier de 10 sec. à 60 sec. sans obtenir de modification ; c'était amplement suffisant ; cela tient à ce que pratiquemment la vitesse d'écoulement du corps plastique est très inférieure à la vitesse à laquelle on fait croitre la pression.

On opérait ainsi successivement sur trois cubes, à la température ordinaire, sans allumer le four, puis sur trois cubes à 600° puis à 700° etc.... jusqu'à 1500°C. Il ne fut pas possible de dépasser 1500°C. non parce que le four était arrivé à sa limite de montée, parce qu'on ne put pas trouver une matière suffisamment résistante pour les cylindres supports. Peut-être des cylindres en carbone eussent-ils répondus aux conditions nécessaires mais il aurait alors fallu prendre des précautions pour eviter leur combustion et l'emploi n'en fut pas tenté. D'ailleurs au-dessus de 1500° l'usage du couple devient également difficile, les tubes de silice qui contiennent les fils de Pt. se ramollissant fortement.

Nous avons dit antérieurement que la valeur de la charge de rupture à la température ordinaire ne pouvait pas faire préjuger de celle à une température plus élevée ; le tableau ci-après justifie cette affirmation en indiquant la résistance de différentes matières éprouvées : à 20° C., à 800°, à 1000°, à 1300°, et à 1500°C.

Désignation :	*Charge de rupture en Kg/cm².* à la température ordinaire (20°c)	à 800°c	à 1000°c	à 1300°c	à 1500°c
Produits silico-alumineux : (série alumineuse)					
Argile A	195	125	105	740	40
Argile C L	920	555	575	360	65
Argile P	1110	485	1755	115	20
Produits d'alumine :					
Bauxite	395	270	715	55	20
Corindon	790	530	615	310	30

Aggloméré de carborundum	415	425	585	150	70
Briques de silice :					
A	277	,,	,,	,,	116
B	276	,,	,,	,,	27
C	244	,,	,,	,,	53
D	171	,,	,,	,,	1
S	180	90	80	60	40
V	240	125	185	160	100
Quartz fondu	2550	1040	780	1670	100
Zircone impure	395	275	345	90	10
Produits de magnésie :					
d'Eubée	260	265	230	110	5
de Styrie	450	205	190	155	30
Produits de fer chromé ..	450	450	425	215	75

Les courbes des charges de rupture en kg/cm² en fonction des températures de ces produits sont reproduites fig. 1 ; sauf pour le fer chromé et la magnésie, la forme de ces courbes fut assez inattendue et je ne me persuadai, qu'elle correspondait bien à la réalité, et n'était pas dûe au hasard ou à des erreurs d'expériences qu'après avoir effectué un grand nombre d'essais.

Les observations qu'on en peut tirer sont les suivantes :

I. *La plupart des produits réfractaires et notamment tous les produits silico-alumineux, alumineux et de silice subissent quand on les chauffe une diminution de résistance avec un minimum généralement vers* 800°*C.*

II. *Les mêmes produits lorsqu'on continue à les chauffer subissent une brusque augmentation de résistance avec un maximum généralement vers* 1000°. *La valeur de ce maximum peut pour certaines argiles atteindre et dépasser même quatre fois celle du minimum.*

III. *Lorsqu'on continue à élever la température, tous les produits réfractaires subissent une chute progressive de résistance, celle-ci tendant à devenir nulle vers* 1600°*C.*

IV. *Généralement à partir d'une température voisine de* 1200° *tous les produits réfractaires deviennent plastiques ou semi-plastiques ; ils n'ont plus de rupture brusque, mais s'écrasent à la manière d'éprouvettes de plomb ou de laiton.*

Sans vouloir chercher les raisons de ces particularités pour lesquelles il n'a pas encore été fourni d'explication satisfaisante nous allons examiner quelles sont les conséquences pratiques qu'on en peut tirer.

I. *Minimum.* C'est l'existence de ce minimum mis en évidence par nos expériences et qui croyons-nous n'avait jamais été signalé auparavant, qui à nos yeux présente l'intérêt pratique le plus considérable ; toutes les maçonneries réfractaires passent en effet, pendant la phase de l'échauffement et celle du refroidissement par la température critique correspondant à la résistance minima ;

il peut s'y produite des accidents dont la cause était jusqu'ici inconnue et qui ne peuvent être évités que si l'on a déterminé la courbe de résistance des matériaux et calculé les constructions en conséquence.

Si Gary avait opéré non seulement à 1000° mais à 700 et 800 il eut vraisemblablement trouvé à ces températures des charges de rupture inférieures à celles à la température ordinaire et en aurait sans doute conçu quelque crainte pour la solidité des empilages pendant les périodes d'échauffement et de refroidissement.

Enfin il est probable qu'alors qu'il est jusqu'ici reconnu impossible de faire varier la température de fusion d'une brique réfractaire en modifiant sa composition mécanique, la grosseur des grains de chamotte, sa compacité.....,il est possible par contre d'influer par ces moyens sur la valeur de sa résistance minima et par conséquent d'améliorer sa qualité.

M. Henry le Châtelier a signalé qu'une élévation de la température de cuisson était susceptible d'augmenter les propriétés réfractaires d'une argile.

Nous avons effectué dans ce même but deux séries d'expériences sur une même bauxite, en opérant pour la première sur des cubes cuits à 1300°, et pour la deuxième sur des cubes cuits à 1500°.

La composition chimique de cette bauxite était la suivante :

Silice	13·30
Acide titanique	3·35
Alumine	61·05
Sesquioxyde de fer	4·75
Chaux	0·95
Magnésie	0·10
Anhydride sulfurique	Traces
Perte au feu	16·45
Non dosé et pertes	0·05
Total ..	100·00

Les résultats sont résumés dans le tableau ci-dessous.

Température en degrés C.	*Charge de rupture en kg/cm².* Bauxite cuite à 1300°C.	Bauxite cuite à 1500°C.
20	595	660
600	300	380
700	285	350
800	270 minimum	360 minimum
900	350	570
1000	715 maximum	685 maximum
1100 (x)	330	500
1200	120	260
1300	55	95
1400	30	40
1500	15	15

(x) Température à partir de la quelle le produit s'écrase comme un corps plastique.

On voit d'aprés ce tableau et les courbes de la fig, 1, que dans les deux cas la température où la bauxite devient plastique est la même, que le minimum et le maximum ont lieu sensiblement aux mêmes

températures, mais que les charges de rupture des cubes cuits à 1500°C. sont toujours supérieures à celles des cubes cuits à 1300° ce qui semble confirmer l'observation de M. Henry le Châtelier et montre que la qualité réfractaire de la bauxite s'est améliorée lorsqu'on a augmenté sa cuisson.

Il aurait été très instructif de choisir une argile, d'en tracer la courbe, puis de fabriquer avec cette argile crue et cuite des cubes contenant différentes proportions d'eau, pressés et non pressés et cuits à différentes températures, d'en tracer les courbes et de comparer tous les résultats obtenus ; mes travaux ont été malheureusement interrompus avant que je ne puisse exécuter ce programme.

II. *Maximum.* L'existence du maximum n'a pas la même portée pratique que celle du minimum ; elle présente aussi pourtant un certain intérêt ; tous les produits n'ont pas en effet leur maximum à la même température ; il faudrait entreprendre des recherches systématiques pour déterminer les conditions qui peuvent faire varier sa valeur et la température à laquelle il se produit ; il est évident que si l'on pouvait choisir les matériaux réfractaires de façon que leur température d'emploi soit justement celle de leur résistance maxima ils se trouveraient placés dans des conditions de conservation éminemment favorables.

On a émis l'hypothèse que ces variations de résistance pouvaient être dûes à des cristallisations qui se produiraient dans la matière sous l'influence de la température ; cette explication est peu satisfaisante en raison de la rapidité de l'opération qui dure une heure à peine ; il est plus vraisemblable comme l'a indiqué M. Bigot qu'il se produit des modifications physiques, telles que des variations du coëfficient de dilatation ; il est possible aussi, et j'avais eu à un moment l'idée de faire des recherches dans ce sens, que la fragilité du produit diminue beaucoup à partir d'une certaine température et qu'on puisse expliquer, de cette façon, au moins dans certaine mesure, l'accroissement de la charge de rupture; dans l'écrasement de ces matériaux en effet il est à présumer que la fragilité intervient parce qu'il est pratiquemment impossible d'avoir pour les supports et pour les éprouvettes des surfaces parfaitement dressées ; dans ce cas, ce serait seulement la première action du ramollissement qui se ferait sentir ; il serait suffisant pour empêcher des ruptures prématurées, mais insuffisant encore pour rendre le produit plastique.

III & IV. *Chute de résistance et plasticité.* La diminution de la résistance au delà du maximum, à mesure que croît la température, et la constatation de la plasticité ou de la semi-plasticité n'ont rien de surprenant. Tous les produits devenant liquides à une température suffisamment élevée, il est naturel qu'ils passent auparavant par un état intermédiaire plus ou moins pâteux où ils présentent une résistance moindre et la consistance de produits plastiques.

Nous avons dit antérieurement que la température, à laquelle se manifestait l'apparition de ce phénomène, était d'environ 1200°C. En réalité il y a quelques variations suivant les produits et voici

les chiffres relevés au cours des expériences sur les matières figurant au tableau page 5.

Argile A	1300°C.
Argile C L	1200°C.
Argile P	1100°C.
Corindon	1400°C.
Bauxite	1100°C.
Produits de silice	1400°C.
Quartz fondu	1400·C.
Magnésie	1000°C.

Une objection s'impose à l'esprit à la lecture de ces résultats : la plupart des produits sont employés à des températures supérieures à celles ou ils deviennent plastiques ; *comment dans ces conditions peuvent-ils résister?* L'explication est croyons nous assez simple ; s'ils étaient soumis effectivement dans leur entier aux températures de régime des fours, il est probable qu'ils fonderaient ou se déformeraient sous des charges faibles, souvent même sous leur propre poids, comme les tuyaux de plomb qui au bout de quelques années forment un arc entre deux colliers consécutifs, mais en réalité ils n'ont qu'une de leurs faces exposée à la température intérieure du four et commé ils sont mauvais conducteurs de la chaleur, leur température décroît rapidement à mesure qu'on s'éloigne de cette face ; dès lors celle-ci peut se ramollir, le reste de la pièce ou de la brique résiste et suffit à maintenir la solidité de la construction.

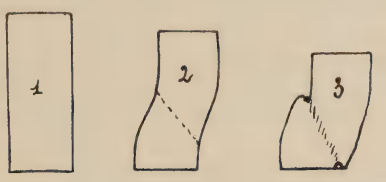
Méthode de la détermination de la température d'affaissement sous charge.

La méthode qui vient d'être décrite précédemment a l'inconvénient de nécessiter un outillage spécial couteux ; la machine de Frémont devrait d'ailleurs être modifiée, elle devrait être plus puissante et permettre de disposer de plus de place pour le four. Les expériences sont longues ; le tracé d'une courbe ne nécessite pas moins de 30 ou 40 opérations d'écrasements.

On a cherché des procédés plus simples et plus rapides. L'un de ceux couramment employé actuellement consiste à chauffer un cylindre ou un prisme sous une charge déterminée et à noter la température à laquelle il s'affaisse. C'est ainsi qu'opère en Angleterre, depuis plusieurs années le Docteur J. W. Mellor et que nous opérons nous-mêmes actuelle-ment au Laboratoire du Comptoir des Fabricants de Produits Réfractaires à Ivry. J'avais toujours été surpris jusqu'ici en lisant les publications du Docteur Mellor des faibles charges de rupture qu'il indique, qui sont très inférieures à celles enregistrées dans les expériences relatées précédemment. Récémment j'ai eu la possibilité, grâce à l'obligeance du Docteur Mellor, d'assister à un essai exécuté à son Laboratoire de Stoke-on-Trent ; j'ai opéré moi-même à Ivry d'une façon analogue et je me suis aperçu de la cause de ce désaccord.

Au lieu d'utiliser des éprouvettes cubiques comme je le faisais au Conservatoire des Arts & Métiers, on emploie des prismes dont la hauteur est 2 fois 1/2 environ le côté. Ils sont chargés au moyen

d'un levier amplificateur : pendant l'opération, soit par flambage, soit par suite déplacement du levier, la baguette prend la forme d'un S et finit par se rompre suivant un plan incliné ainsi que le montre la figure.



Dans ces conditions, nous avons observé que sous une charge de 10 kg/cm², un produit silico-alumineux à 30% d'alumine s'affaissait à une température de 1520°, une bauxite à 1420°.

La marche d'une expérience est la suivante : Aprés avoir placé le prisme dans le four entre ses deux supports et muni le levier d'une surcharge convenable, on allume le four dont la température s'élève progressivement ; dans notre dispositif le four est analogue à celui décrit au début de cet article ; la température est indiquée de la même façon au moyen d'un couple thermo-électrique platine—platine-rhodié qui traverse le four au moyen d'un tube spécial et dont la soudure est amenée au voisinage immédiat de l'éprouvette.

En Angleterre le four est électrique et la température est contrôlée au moyen de montres fusibles placées tout autour de l'éprouvette.

On observe les déplacements de l'extrêmité du levier ; sous l'influence de la dilatation des parties métalliques de l'appareil elle commence par s'élever jusque vers 1200° puis ensuite elle redescend avec une vitesse croissante, jusqu'au moment où se produit l'affaissement complêt correspondant à la rupture de l'éprouvette.

J'avais pensé qu'il serait peut-être possible de noter l'affaissement aux différentes températures, mais la marche des expériences a été trop rapide pour qu'il ait été possible de la faire ; on pourrait cependant la ralentir à cet effet, et il serait instructif d'enregistrer le diagramme des affaissements en fonction des températures.

Conclusion. Quoiqu'il en soit, si cette méthode à l'avantage d'être simple et rapide et de donner cependant un moyen de comparaison intéressant des matériaux réfractaires entre eux, elle ne met pas à notre disposition un moyen d'investigation aussi souple que le procédé décrit précedemment ; par suite de la faible surcharge, on n'obtient aucune indication sur la valeur du minimum et du maximum ; et on ne recueille de renseignement sur le produit, que dans la zone correspondant à la branche descendante de la courbe au delà de la température où le produit devient plastique.

Il faut donc souhaiter que la méthode que j'avais employée

puisse être reprise avec une machine faite spécialemént dans ce but et que les essais systématiques qu'il ne m'a pas été possible d'exécuter puissent être entrepris. Ils ne manqueront pas 'apporter quelque lumière, et une nouvelle contribution à l'étude de cette question si complexe qu'est la détermination de la qualité des produits réfractaires.

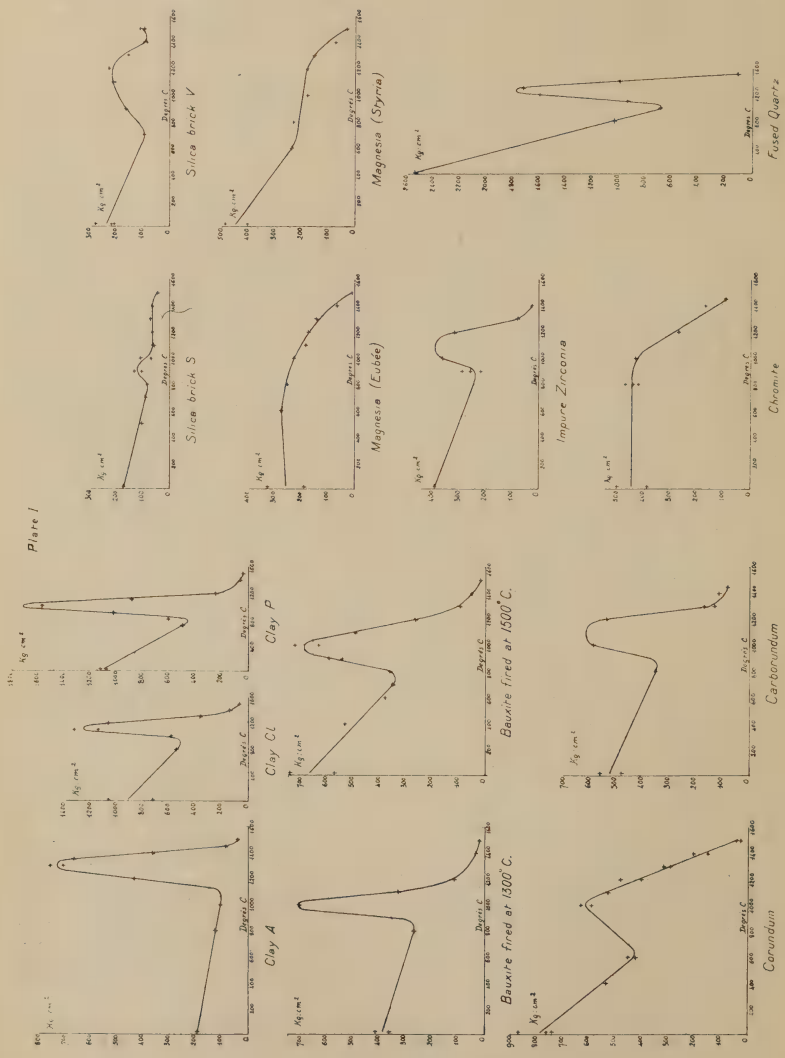


Fig. 1.

Courbes des charges de rupture in kg/cm² en fonction des températures.

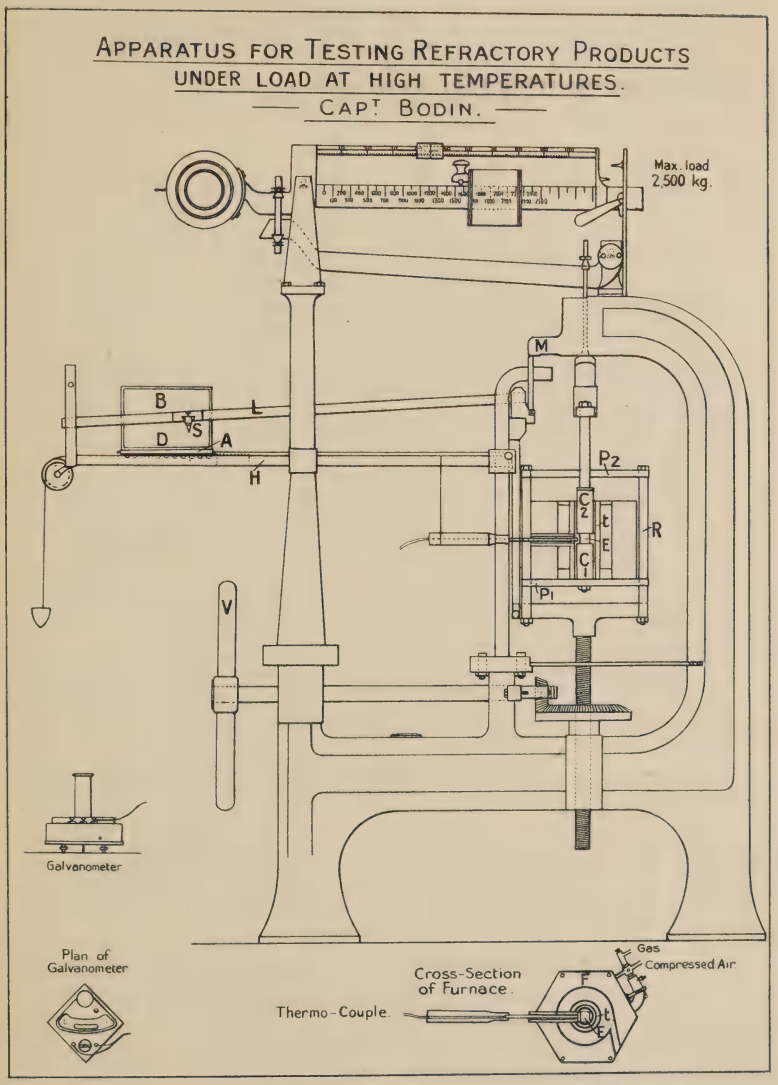


Fig. 2.
Dispositif du Capitaine Bodin
pour l'écrasement à chaud des produits réfractaires.

II.—Resistance Tests on Refractory Products under Load at different Temperatures.

By V. Bodin.

(*Translation by F.S.*)

IN testing the properties of refractory products, one of the most useful qualities to investigate is their *ability to support a load at different temperatures.*

Owing either to their height, or to the fact that heavy objects are placed permanently or at intervals on the upper sections, furnace structures often have to support quite a considerable load ; furthermore, if the materials used tend to expand, the pressure developed in the arch may be by no means negligible.

For a long time, investigations were limited to the determination of the crushing strength at ordinary temperatures, owing to the experimental difficulties met with when working at high temperatures. But this, as we shall see later, bears no relation to the crushing strength at different temperatures ; for practical purposes therefore, it is only of secondary importance to the users of refractory materials.

When purchasing materials, however, it is advisable to insist on a minimum strength at ordinary temperatures in order to avoid damage during transport, but this condition does not imply that they will exhibit good resistance qualities at high temperatures.

Neither is a knowledge of the fusing temperature of any assistance in the matter, for, in spite of the uncertainty which still prevails as to the softening temperatures of different products, there can be no doubt that the disparity between the softening and fusing temperatures varies between very wide limits according to the material ; it is very considerable, for instance, for bauxite and particularly for magnesia, but much less pronounced for silica products.

It was therefore natural that investigators should endeavour to find a method of determining directly the crushing strength at different temperatures. The first tests were carried out, if my information is correct, by Professor Gary, at the Laboratory in Gross-Lichterfeld. The problem was presented to him by some manufacturers of Cowper stoves. These stoves, as we know, consist of cylinders containing columns of refractory bricks, which are heated by allowing the hot gases from the furnace to pass over them, and are then used to pre-heat the air or gas before passing to the burners. When the height of the stoves had to be increased

for certain reasons, the manufacturer found that the bricks at the bottom collapsed when the temperature reached its maximum, *i.e.*, at about 1000°C.

By means of a special apparatus, Gary compared the crushing strength of several qualities of refractory bricks at 1000°C. and at ordinary temperature. The mean of his results was as follows :

	Ord. Temp.	1000°C.
1. Rhenish brick of commerce ..	169 kg./cm.	218 kg./cm.
2. Brick P.W. 10 ..	148 ,,	163 ,,

From these results, he considered himself justified in concluding that there was no danger of collapse if the resistance at 1000°C. was greater than that at ordinary temperature. We shall see from the following that he would no doubt have abandoned this opinion if he had worked at intermediate temperatures.

During the war, the importance of refractory materials in metallurgy attracted the attention of scientists of the Entente ; in particular, Dr. J. W. Mellor, in England, and M. H. le Châtelier in France, devoted their attention to the resistance of refractory products to pressure at high temperatures. M. H. le Châtelier constructed an apparatus and made a number of experiments, from which he concluded that this resistance diminishes fairly regularly with a rise in temperature. I was then in charge of the Section for Testing Materials at the Testing Laboratory of the Conservatoire National des Arts et Métiers, and had the advantage of being in touch with M. Châtelier, who showed me his apparatus. I followed up the idea and was able to put a similar apparatus into operation. I also had the good fortune to be able, with the assistance then at my disposal, to carry out a large number of experiments.

Most of the products tested were supplied to me from Messrs. Ch. Guérineau & Co., by M. A. Bigot, who has been unstinting in his encouragement and assistance, placing his unrivalled experience in all branches of ceramics at my disposal.

The results obtained enabled me to trace a curve for each product showing the crushing strength in kg./cm.^{2} as a function of the temperature from room temperature to 1500°C. Some of these curves were published by M. A. Bigot in England* and in France†.

Without recapitulating what has already been said on the system, I should like to add a few details regarding the testing apparatus, and also consider what information and conclusions may be drawn from the results as indicated directly in the form of the curves. I shall then show that other testing methods do not appear to me to supply this information in so complete a form.

Testing Apparatus. The instrument used for producing the

*See Trans., *Cer. Soc.*, **17**, 259-66, 1918.
†See *Chimie et Industrie*, Dec. 1918, and *La Céramique*, April, 1919.

pressure (Fig. 2) was a Frémont machine for testing metals. It was fitted with a reversing frame R constructed specially, and as large as possible, so that a spiral flame furnace F, also specially made for these experiments, could be placed between the two plates. This furnace, fired with gas and compressed air, can be readily seen in the figure, where it is shown in section and in elevation. The flame moves in an annular space, the central tube t, open at both ends, forming a sort of muffle. In this tube, the test piece E, cut in the shape of a cube, 20 mm. square, is placed between two cylindrical blocks C_1 C_2, which transmit the pressures. The lower plate of the apparatus, P_1, is fixed ; upon it rests the block C_1 supporting the sample. The upper plate P_2 on the other hand is moveable ; it can be made to descend, and thus bring about the crushing of the sample, by acting on the lower screw by means of the wheel V which moves the gears.

The temperature is measured continuously by means of a platinum platinum-rhodium couple, placed in a small tube passing through the central tube t, so that the junction is brought into close contact with the sample being tested. Some slight difficulty was experienced in placing the cube in the centre of cylinder C_1 ; it was observed that, in spite of the precautions taken, its position was frequently unfavourable. This was remedied by attaching the cube to its support by means of a low-temperature cement.

The Frémont machine is fitted with a recording apparatus D ; a carriage A is moveable along two knife-edges H. It is attached by a wire to the two plates, and its displacement is proportional to that of P_2 relative to P_1. On this carriage is mounted a framework B, to which a sheet of paper is fixed. By means of a pencil attached to a lever L, consisting of a thin tube, the pressures developed by the machine can be registered ; these are, as a matter of fact, proportional to the movements of part M of the machine, which acts on the lever.

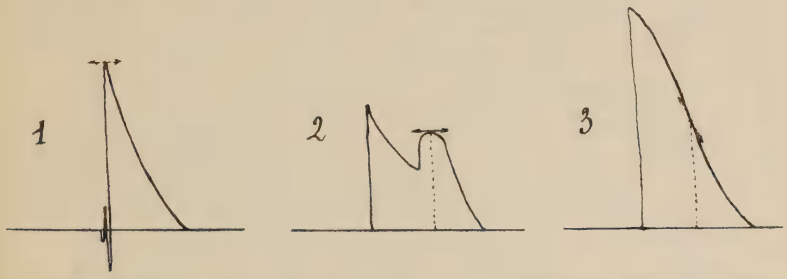
The carriage slides along the knife-edges on four sockets, but to render it more mobile we had it mounted on rollers running in two grooves. We never relied, however, on the displacements of the carriage for measuring the amount of squatting of the sample, for, owing to the possible elongation of the wire and to the fact that certain metallic parts of the machine inevitably became hot, no precise indication could be expected. On the other hand, the curves obtained enabled us to determine the crushing load, from the preliminary pressure exerted by the lever of the machine.

The possibility of tracing these squatting curves and of observing their form is a most important factor, to which the success of these experiments must in a large measure be attributed.

Tests are carried out in the following manner : The lower support together with the sample cube are introduced into the cold furnace ; the upper cylinder and the thermo-couple are then placed in position, and the furnace started. About an hour is required to reach a

temperature of 1500°C. Having arrived approximately at the desired temperature, the furnace is regulated so as to considerably diminish the rate at which the temperature rises. The recording apparatus is then put in readiness and the squatting of the sample effected by turning the wheel. The last part of the operation is completed in less than a minute.

According to the temperature and the nature of the test piece, the curve obtained may present one of three different characteristic forms :



Curve No. 1 corresponds to an abrupt collapse of the substance as effected at ordinary temperatures ; this type of curve is usually observed up to about 1100 or 1200°C. At higher temperatures, curves of the form 2 or 3 are generally obtained. Curve 2 corresponds to the collapse of a semi-plastic substance, such as is generally produced by alumino-silicate products with grog or quartz added. Curve 3 represents the squatting of a plastic body, such as a pure clay.

In the case of curve 2, the collapse of the sample is brought about by certain factors, so that the curve falls, and then rises again. If the experiment is carried further, several successive apices will be found in the curve. The first apex was taken in every case to measure the crushing load. This curve, which represents a transition between 1 and 3, may, however, assume various forms.

Curve No. 3 indicates no actual collapse ; the pressure rises indefinitely, but without the curve recorder it would have been impossible to obtain any indication of this. This form of curve exhibits a point of inflexion and is similar to one obtained on compressing a small cylinder of soft metal such as lead or brass. By anology, and guided also by the other transitional curves, the load given by the ordinate of the point of inflexion was taken as the crushing load.

It may be asked whether, under these conditions, the time taken for the performance of the operation does not materially affect the shape of the curve. Experiments carried out with this point in view showed, however, that the time might be varied from 10 to 60 seconds without any modification of the results. This is so, because the rate at which a plastic body cools is very

much lower than the rate at which pressure is applied.

This method of testing was applied successively to 3 cubes at ordinary temperatures in a cold furnace, and then to 3 cubes at 600°C., at 700°C., etc., to 1500°C. It was found impossible to exceed 1500°C., not on account of the furnace temperature-limit having been reached, but because a sufficiently refractory material for the cylindrical supports could not be obtained. Carbon cylinders might have proved capable of satisfying the conditions, but it would then have been necessary to take precautions to avoid combustion taking place. Their use was therefore not attempted. Furthermore, above 1500°C. the use of the couple also became increasingly difficult, since the silica tubes containing the platinum wires softened considerably.

As previously stated, the value of the crushing load at ordinary temperatures gives no indication of the corresponding figure for higher temperatures. The following table, showing the resistance figures for various substances tested, at 20°C., 800°C., 1000°C., 1300°C., and at 1500°C., justifies this statement:

Substance Tested.	*Crushing load in kg./cm.²* At ordinary temp. (20°C.)	at 800°C.	at 1000°C.	at 1300°C.	at 1500°C.
Alumina-silicate Products. (Aluminous series):					
Clay A	195	125	105	740	40
Clay C L	920	555	575	360	65
Clay P	1110	485	1755	115	20
Alumina Products:					
Bauxite	395	270	715	55	20
Corundum	790	530	615	310	30
Carborundum	415	425	585	150	70
Silica Bricks:					
A	277	,,	,,	,,	116
B	276	,,	,,	,,	27
C	244	,,	,,	,,	53
D	171	,,	,,	,,	1
S	180	90	80	60	40
V	240	125	185	160	100
Fused Quartz	2550	1040	780	1670	100
Impure Zirconia ..	395	275	345	90	10
Magnesite Bricks:					
From Eubœa	260	265	230	110	5
,, Styria	450	295	190	155	30
Chromite Bricks	450	450	425	215	75

The curves showing the crushing loads as a function of the temperatures for these products are given in Plate I. With the exception of the chromite and magnesia, the shape of these curves

was rather unexpected, and it was only after having carried out a large number of tests that I was convinced that they are a true representation of the facts, and not due to chance or to experimental error. The deductions which may be drawn from them are as follows:

1. *The majority of refractory products, particularly all the silico-aluminous, aluminous and silica products, show a tendency to decreased resistance to load on heating, the minimum being generally at a temperature round about* 800°C.
2. *The same products, on further heating, exhibit a rapidly increasing resistance, with a maximum usually at about* 1000°C. *For certain clays, this maximum may reach and even exceed four times the minimum.*
3. *With a still further rise in temperature, a progressive decline in resistance, tending towards zero at about* 1600°C., *is observed with all refractory products.*
4. *In general, all refractory products tend to become plastic, or semi-plastic beyond a temperature bordering on about* 1200°C. ; *they subside after the manner of lead or brass samples, no further abrupt rupture taking place.*

Without attempting to give reasons for these peculiarities, for which sufficient explanation is not yet forthcoming, we will proceed to draw from them a few practical conclusions.

I. *The Minimum.* It is the existance of this minimum, which has been demonstrated by our experiments, and to which we believe attention has never been called previously, that is of the greatest practical interest. The whole of the refractory masonry of a furnace passes through the critical range of temperature corresponding to the resistance-minimum, during the heating and cooling process. Trouble may then be experienced, the cause of which has hitherto been unknown, and which could only be avoided by determining the resistance curves of the materials and arranging the construction accordingly.

If Gary had worked not only at 1000° but also at 700° and 800°C. he would certainly have found the crushing strengths at these temperatures to be lower than those at ordinary temperatures.

Further, though it has hitherto been found impossible to vary the fusing temperature of a refractory brick by modifying its mechanical composition—size of grog, compactness, etc.—it may probably be found possible to affect the minimum-resistance figure by this means, and thus improve the quality of the brick.

M. H. de Châtelier found that increased firing temperature tended to increase the refractoriness of a clay. We also carried out two series of experiments in this connection on a bauxite, using in the first case samples fired at 1300°C., and in the second case similar samples fired at 1500°C. The chemical composition of the bauxite was : Silica 13·3%, titanic oxide 3·35, alumina 61°05, sesquioxide of iron 4·75, lime 0·95, magnesia 0·10, traces of sulphur trioxide,

loss on ignition 16·45, The results obtained are given in the following table :

Temperature in degrees C.	*Crushing Load in Kg/cm.²*. Bauxite fired at 1300°C.	Bauxite fired at 1500°C.
20	395	660
600	300	380
700	285	350
800	270 minimum	360 minimum
900	350	570
1000	715 maxmium	685 maximum
*1100	330	500
1200	120	260
1300	55	95
1400	30	40
1500	15	15

*Beyond this temperature the sample subsided in the same way as a plastic body.

From this table, and the curves on Plate I., it can be seen that the temperature at which the bauxite becomes plastic is the same, that the minimum and maximum take place at practically the same temperatures, but that the crushing loads for the cubes fired at 1500°C. are always higher than those for the cubes fired at 1300°C. This appears to confirm M. Châtelier's observations and shows that the refractory properties of bauxite are improved by firing at a higher temperature.

It would have been very instructive to have chosen a clay, trace its curve, then make cubes of the raw and fired material containing varying proportions of water, pressed and unpressed, and fired at different temperatures, plot the different curves, and compare all the results obtained. But, unfortunately, my work was interrupted before I could carry out this programme.

II. *The Maximum.* The existence of the maximum is not of the same practical import as that of the minimum ; it is nevertheless interesting in certain respects. The maximum is not observed at the same temperature for all products ; systematic research ought therefore to be undertaken to determine the conditions which would alter its value and the temperature at which it is produced. It is evident that, if refractory materials could be chosen such that their working temperature were exactly that of their maximum resistance, we should be working under conditions eminently favourable to their durability.

The hypothesis has been put forward that these variations in resistance may be due to crystallisations brought about in the substance under the influence of temperature. This explanation is hardly satisfactory in view of the rapidity of the operation, which barely lasts an hour. It is more probable that, as indicated by M. Bigot, certain physical modifications, anologous to the variations in the coefficient of expansion, take place. It is also possible—and at one time I thought of undertaking some research work in this sense—that the weakness or brittleness of the substance

diminishes greatly beyond a certain temperature, and that the increase in the crushing strength may to a certain extent be thus accounted for. Presumably, brittleness has a bearing on the crushing of these materials, since it is practically impossible to render the surfaces of the supports and test-piece absolutely smooth. In this case it would only be the first softening action which would make itself felt. It would be sufficient to prevent premature rupture, but insufficient to render the product plastic.

III. & IV. *Decline in Resistance, and Plasticity.* Decreased resistance to load beyond the maximum as the temperature rises, and the commencement of plasticity, or semi-plasticity, present no unusual features. Since all substances become liquid at a sufficiently high temperature, it is natural to expect that they first pass through an intermediate, more or less "pasty" state, in which they assume the consistency of plastic bodies.

It has been previously stated, that the temperature at which this phenomenon occurred, was at about 1200°C. In reality, there are some variations according to the products. The following are the figures obtained from tests on the substances given in the previous table :

Clay A	1300°C.	Bauxite	1100°C.
,, C L	1200°C.	Silica Bricks	1400°C.
,, P	1100°C.	Fased Quartz	1400°C.
Corundum	1400°C.	Magnesia	1000°C.

One point demands attention on considering these results : the majority of the products are employed in practice at temperatures higher than those at which they become plastic. The question then arises as to how, under these conditions, they can offer resistance to load. The explanation is, we believe, quite simple ; if the entire bricks were submitted to the working furnace temperatures, it is possible that they would collapse or become distorted under a slight pressure, often even under their own weights, but in reality only one surface is exposed to the inner furnace temperature, and since they are bad conductors of heat, the temperature decreases rapidly as the distance from the exposed face increases. Although this surface may soften, the remainder of the brick is still strong enough to support the structure.

Method of Determining the Squatting Temperature under Load. The method described above has one disadvantage, in that it requires special and expensive apparatus. The Frémont machine has to be modified; it has to be made more powerful, and must allow of sufficient space being found for the furnace. The experiments take a long time ; not less than 30 or 40 crushing tests are necessary to plot a curve.

Simpler and more rapid methods have been devised, one of which, in use at present, consists in heating a cylinder or prism under a given load and noting the temperature at which it collapses.

For several years, Dr. J. W. Mellor has employed this method

in England, and we ourselves are now using it at the Refractory Manufacturers' Laboratory, at Ivry.

On reading Dr. Mellor's publications, I have always been surprised at the low figures given in them for the crushing loads, which are much lower than those registered in the experiments described above. By the kindness of Dr. Mellor, I recently had the opportunity of being present at a test carried out at his laboratory at Stoke-on-Trent. I have also been working by a similar method myself at Ivry, and have now discovered the cause of this discrepancy.

Instead of using cubical samples, prisms are employed, the height of which is about $2\frac{1}{2}$ times the side. Pressure is exerted by means of a magnifying lever. During the experiment, the sample, owing either to the heat, or to the displacement of the lever, takes the form of an S and finally ruptures on an inclined plane as shown in the figure.

Under these conditions, it was observed that, under a pressure of 10 kg /cm.^{2}, an alumino-silicate product (30% alumina) collapses at a temperature of 1520°C., a bauxite at 1420°C.

An experiment is carried out as follows: After having placed the prism between its two supports in the furnace, and applied a suitable load to the lever, the furnace is started and the temperature allowed to rise regularly. In our apparatus, the furnace is the same as that described at the commencement of this article, and the temperature is measured in a similar manner by means of a thermo-couple. In England, electric furnaces are used, and the temperature is read by means of cones placed all around the sample.

The displacement of the extremity of the lever is observed; under the influence of the expansion of the metallic parts of the apparatus, it begins by rising until about 1200°C. is reached. It then falls at an increasing rate, until the collapse of the sample takes place.

I had considered the possibility of noting the crushing strength at different temperatures, but the tests are carried out too rapidly to render this practicable. It may, however, be possible to reduce the speed at which the operation is conducted for this purpose, and it would be interesting to trace diagrammes showing the crushing strengths as functions of the temperature.

Conclusion. Although this method has the advantage of being simple and rapid, and of supplying an interesting means of comparing one refractory material with another, it does not place at

our disposal such an adaptable experimental method as that previously described. Owing to the smallness of the load, no indication of the minimum and maximum figures can be obtained, and nothing is learned about the material, except at the point corresponding to the descending portion of the curve beyond the temperature at which the sample reaches the plastic state.

The fact that the method employed by me may be carried out with a machine made specially for the purpose, and that systematic tests, hitherto found impracticable, may now be undertaken, will no doubt be welcomed. Such systematic investigation will not fail to throw new light upon, and constitute a new contribution to, a problem so complex as the determination of the properties of refractory products.

III.—Dinas Bricks of Constant Volume.

PRELIMINARY NOTE.

By O. Rebuffat.

AFTER having been in use in high temperature furnaces over a more or less lengthy period of time, silica bricks often show a tendency to disintegrate owing to expansion. This undesirable property has been shown to be due to certain kinds of quartzite used in the manufacture of the bricks.

The study of this phenomenon by numerous men of science has brought out the fact that the expansion of the bricks is the result of the transformation of the quartz into allotropic forms of much lower density, *i.e.*, into tridymite, cristobalite, fused silica, etc. Furthermore, it has been observed that the quartz in bricks made from those quartzites which do not cause expansion after prolonged use in the furnace, had undergone almost complete transformation during the initial firing of the bricks; whilst on the other hand, no such transformation took place in the quartzites during the manufacture of those bricks which expanded in the furnace.

With the object of obtaining quartzite bricks of constant volume, it was proposed to prolong the initial firing until the whole of the quartz had been almost completely transformed into tridymite. This, however, was not practicable in view of the enormous consumption of fuel and material, since it would be necessary to maintain the bricks for several weeks at a temperature of 1400°C.; and even then, success would not be assured. Again, all attempts to arrive at a reliable method of distinguishing a quartzite, which gives bricks of constant volume, from those which do not, have hitherto proved unsuccessful.

This problem, the study of which has now been undertaken by the writer, was among those proposed to the Italian Chemists by the Technical Scientific Society of Milan, at the request of the Ironworks at Terni.

As previously stated, the results of the most reliable investigations carried out hitherto, tend to show that the transformation of quartz into tridymite takes place owing to its dissolution into a glassy flux, from which tridymite crystallises out.

In all silica bricks, the firing leads to the formation of a small quantity of calcium silicate, which serves as a binder for the silica grains; but of itself it obviously does not suffice to facilitate the change from quartz into tridymite. It must, therefore, be admitted, that those quartzites which give products of constant volume, contain some other substance which, on uniting with the calcium silicate, forms the flux which aids in producing the transformation.

It has long been known that certain highly stable and non-volatile inorganic acids, such as boric, phosphoric, tungstic and molybdic acids, form molecular complexes with silicic acid which will dissolve silica and enable it to crystallise into different allotropic forms. To proceed methodically, therefore, the first step was to examine the quartzites which gave bricks of constant volume, in order to determine whether they contained considerable quantities of the above substances. This research was the more necessary, since such quartzites are generally secondary ones with a high non-silica content.

Lagonegro quartzite, which was found by several Italian ironworks to give bricks of constant volume, was examined by the writer. This quartzite leaves a sulphate residue of 5·5% ; in the natural state and at a temperature of 15°C. it has a density of 2·65, whilst after calcining for 8 hours at about 1300—1350°C. it assumes a density of 2·25. Analysis showed that this rock contains 0·31% phosphoric anhydride, some ferric oxide and small quantities of other substances. After washing with concentrated nitric acid to remove the phosphoric acid, it was found that this purified rock lost the property of rapidly diminishing in density on heating to 1300°—1350°. It retained a density of 2·6 after 8 hours burning at this temperature.

As a counterproof, the author then took a quantity of very pure primary quartzite, which left a small sulphate residue of 0·62% and had a density of 2·60 (which was unchanged after heating for 8 hours at 1300—1350°C.) and added to it 3% of an alkali glass with a density of 2·61 and containing 16% of phosphor pentoxide (*i.e.*, 0·45% of the whole quartzite). The mixture was then heated as usual for 8 hours at 1300°—1350°. The resulting product had a density of 2·27—2·30 and examined microscopically with crossed nicols, showed only a few small birefringent grains. It thus resembled in appearance the burned Lagonegro quartzite.

These experiments tend to prove that the transformation of quartz into allotropic forms of much lower density is facilitated by the presence of small quantities of phosphoric acid. This latter substance has been identified in the Lagonegro quartzite, which rapidly undergoes transformation on heating. (Patent applied for).

In view of the wide distribution of phosphoric acid in rocks, it is hardly stretching the point to assert that, if certain quartzites have the property of giving bricks of constant volume, it is due to the presence of small quantities of this substance in them.

Microscopic examination of all the author's preparations showed that the allotropic varieties of silica formed under these conditions consist mainly of tridymite. If the heating is prolonged for more than 8 hours, the tridymite structure becomes more and more uniform, while the rare birefringent grains that were first noted entirely disappear.

The writer has not determined definitely whether other allot-

ropic forms of low density are present in small quantity; but even after heating for 24 hours at 1300—1350°C., the tridymite structure appears uniform and the density remains at 2·22 to 2·27.

This preliminary note is soon to be followed by a fuller account both of the research work already carried out and that which is at present being undertaken.

IV.—Notes on American Practice in Refractories.

By W. J. Rees, F.I.C.

AT the outset of this note the writer desires to express his appreciation of the cordiality of the reception he received from manufacturers of refractories in the United States and Canada during his visit in the autumn of last year. Almost without exception every facility was accorded for the inspection of manufacturing operations and thanks are particularly due to Mr. Kenneth Seaver, (Harbison Walker Refractories Co.); The Mount Union Refractories Co.; Mr. C. B. Stowe, (Federal Refractories Co.); Mr. K. Kilbourne, (Scottish-Canadian Magnesite Co.); and to Mr. Raymond Howe, of the Mellon Institute of Industial Research, University of Pittsburgh.

The outstanding feature of American practice is the well-developed organisation of plant for maximum production with minimum costs. Mechanical methods for handling the raw materials and conveying prepared brickmaking batches to the brickmakers, are general and the elimination of hand labour is a marked feature of the larger plants.

The principle sources of raw material for the making of silica bricks are the Medina quartzites (lower Silurian) of Central Pennsylvania; the Baraboo (Pre-Cambrian) quartzites of Wisconsin, and the Cambrian quartzites of Alabama. Bricks are also made from the quartzites quarried in Maryland, Colorado and California. Figs. 1, 1a, 2, 3, 4 and 5, are photomicrographs of these quartzites.

The chemical composition of the most important ones is as follows:—

	Medina.	*Baraboo.*	*Alabama.*
SiO_2 ..	97·80	97·15	97·70 per cent.
Al_2O_3 ..	0·90	1·00	0·96 ,,
Fe_2O_3 ..	0·85	1·05	0·80 ,,
CaO ..	0·10	0·10	0·05 ,,
MgO ..	0·15	0·25	0·30 ,,
K_2O .. } Na_2O .. }	0·40	0·10	0·31 ,,

Probably more than half of the raw stone used in making silica bricks in America is obtained from the Medina formation. The uppermost portion of this is composed of massive beds of hard white or greenish white quartzite; the middle division consists of a softer red quartzite underlain by shales whilst the lower portion consists of a harder quartzite frequently rather ochreous. The hard white upper beds are frequently several hundreds of feet in thickness being in some places nearly horizontal and at others

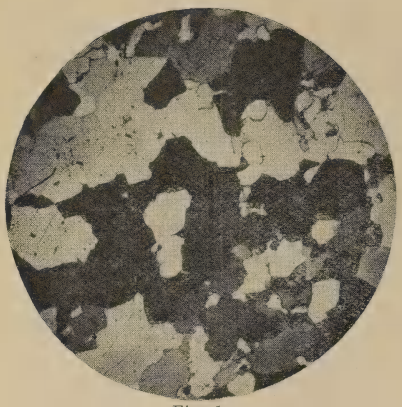


Fig. 1.

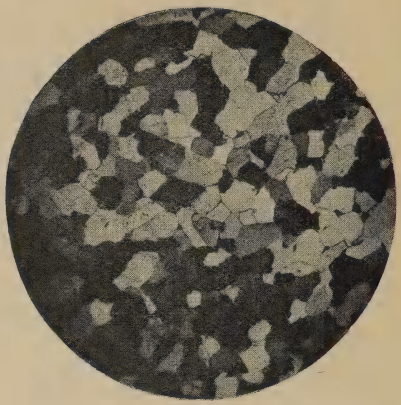


Fig. 1a.

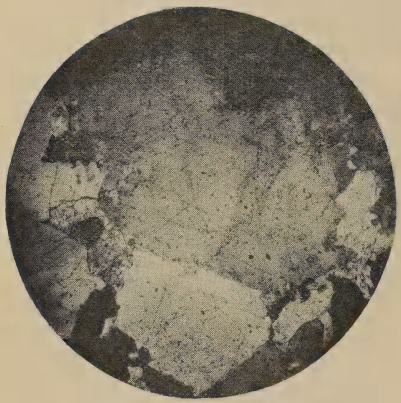


Fig. 2.

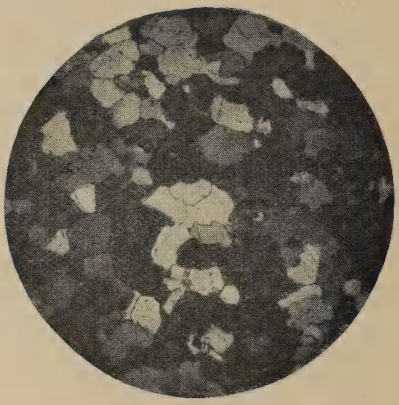


Fig. 3.

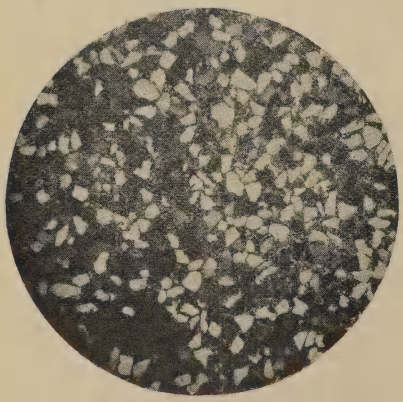


Fig. 4.

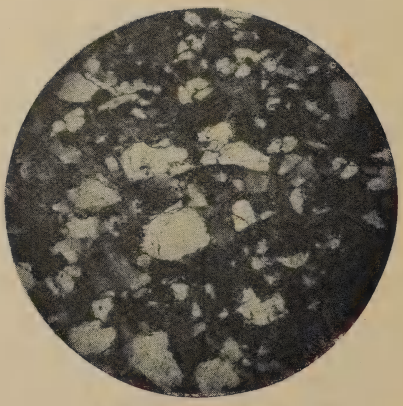


Fig. 5.

Fig. 1. Medina Quartzite from talus slope, between crossed nicols. × 20.
Fig. 1a. Medina Quartzite, between crossed nicols. × 20.
Fig. 2. Baraboo Quartzite, ,, ,, × 20.
Fig. 3. Maryland Quartzite, ,, ,, × 20.
Fig. 4. Colorado Quartzite, ,, ,, × 20.
Fig. 5. Californian Quartzite, ,, ,, × 20.

steeply inclined. The softer lower beds soften on weathering and as a result the hard white upper beds break away and form extensive "ganister floes" frequently many feet in thickness and covering upwards of 1000 acres. Much of the raw stone is obtained from these talus slopes (Figs. 6 & 7) but the beds of massive stone are also extensively quarried. This quartzite consists essentially of closely packed and interlocking quartz crystals, each with a sand grain as nucleus. There is little or no ground-mass or binding material, the spaces between the original sand grains having been filled with secondary quartz which has attached itself to the original grains in crystalline continuity with them.

A typical flow sheet of the raw materials in a large plant is as follows:—

Hopper wagons with lump stone.
Gyratory Crusher.
Rotary Screen.
By bucket elevator to jaw crusher, reducing to 3" size and under.
By belt conveyor to stone bins or stone store.
Solid bottom pan.
By elevator and belt conveyor to bins for brick batch.
Brickmaking tables or machine.

The hopper wagons carrying 40 to 50 tons of stone are at a high level, the discharge to the gyratory crusher (crushing 2 or 3 tons per minute) and to the rotary screens being by gravity. Below each crushed stone-bin is a pivoted measure holding approx. 800 lbs. of stone, the tipping of the measure (to deliver the stone to the solid-bottom pan) closing the mouth of the bin. A definite weight of stone is thus charged into the pan. A pre-determined weight of lime (of known CaO content) is placed in a vessel above each pan, water added and milk of lime prepared by agitation; the whole of this milk of lime is then fed into the pan, any large clots or fragments of unburnt limestone being removed by a sieve in the top of the delivery pipe. By this means the proportion of lime to silica is kept constant in successive batches. The normal proportion gives 2% CaO in the bricks but for special purposes this is varied, up to 3% being used for instance for coke oven bricks. The moulds for hand-making are rectangular in shape for ordinary size bricks, each mould making 5 bricks in parallel. The moulds are overfilled by throwing in the batch and they are then rammed hard with a short-handled metal-faced palette about 12 inches square on the face. Much attention has been given to the machine making of silica bricks and a machine has just been evolved by the Refractories Manufacturers' Association which in the writer's opinion will go far to solve this difficult question. Pressure machines have not given a satisfactory brick, the physical properties of pressed bricks comparing unfavourably with those of hand-made bricks. The wear on the moulds in presses is also

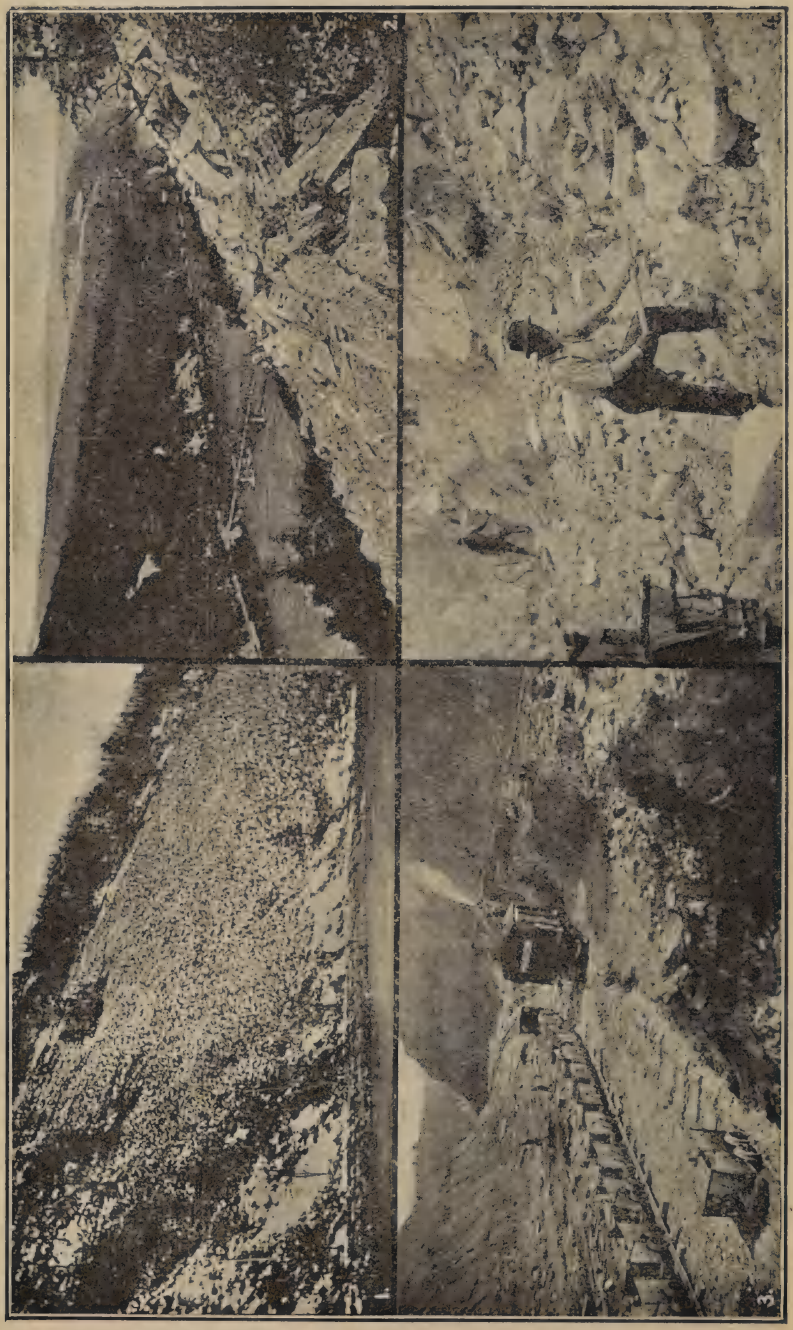


Fig. 6.

Fig. 7.

Fig. 8.

Fig. 9.

very severe, rendering the upkeep expensive. In the newly-developed machine no pressure is used, the normal operations of the handmaking process being translated into mechanical operations. The moulds, making 5 bricks in parallel, on endless chains are filled as they momentarily stop under a vertical chute. Above this chute, which is approx. 20 feet in height, is another endless chain carrying buckets filled with the brick-batch. The movement of the buckets on this upper chain synchronises with the movement of the moulds on the lower chain. As each bucket reaches the upper end of the vertical chute it is suddenly and completely tipped over so that the batch it contains falls and fills the mould which is in position at the lower end of the chute, a very satisfactory imitation of the operation of throwing the batch into the moulds in the hand making process thus being obtained. The moulds, which are slightly overfilled, then travel onwards, passing under revolving brushes and blades which remove the excess material and produce a smooth surface on the brick. The bricks are removed from the moulds by a simple but ingenious mechanical device and automatically transferred to flat iron plates, on which they are removed to the drier cars. The brickmaking batch i made with just sufficient moisture so that when it falls into the moulds it readily fills the corners. The writer saw two of these machines in operation, one having a capacity of 1200 bricks per hour and the other of 3,000 bricks per hour. This latter machine was tended by three unskilled labourers and the bricks produced by it were indistinguishable in porosity, mechanical strengh and other properties from the best hand-made bricks. The cost of production of bricks is greatly reduced by the use of this machine, and its principle of operation seems much more desirable for silica brickmaking than does that of any type of pressure machine. In making large shapes by hand, wooden moulds with loose liners of hard wood or metal are used. The batch is slightly drier than for ordinary bricks and it is at some plants ground for a longer period in the pan in order to increase the plasticity; it is pounded into the moulds with heavy wooden mallets and finally rammed with the metal-faced palette. It is obviously desirable that large blocks should be as stiff as possible when removed from the mould in order to avoid deformation.

The normal time of grinding a mix of 800 to 1,000 pounds of stone, entering the solid bottom in pieces from 3″ size downwards, for use in making ordinary bricks is 15 minutes. In general, no attempt is made to grade the brick batch by pre-mixing graded stone or by adding silica flour to the batch. The hardness of the stone does not vary greatly and the duration of grinding is such that the fortuitous grading produced in grinding gives a product which is considered satisfactory and which is remarkably uniform from batch to batch. The work of Le Châtelier on the addition of a proportion of impalpable powder to the batch is being crit-

ically discussed in research laboratories and its applicability to American raw materials made the subject of experiment in the laboratory and works.

In the smaller plants the bricks are dried on floors heated by waste heat but in the larger plants some type of tunnel dryer is used exclusively. The tunnels are heated by drawing air by means of a low pressure exhaust fan through cooling kilns or, if sufficient heat is not obtainable from these kilns, hot gases are drawn from kilns which are in progress of firing. In this latter case the utilisation in this way of a portion of the hot products of combustion does not interfere with the draft of the kiln or with the duration of burn.

As shown in Fig. 10 the kilns are of the normal circular down-draft type, varying from 30 to 45 feet in diameter, the capacity varying from 90,000 to 175,000 ordinary bricks. In setting, $\frac{1}{2}$-inch is left between bricks to allow for expansion and they are set in benches about 4 feet wide to a height of from 12 to 15 feet. The load on the bottom bricks is about 15 pounds per square inch but with the thorough drying obtained in the tunnel dryers there is no crushing under this load. The duration of burning is from 9 to 12 days, a temperature equivalent to Cones 16 to 18 being attained and maintained for 2 days. From 5 to 8 days are required for cooling the kiln. The coal consumption is approximately 1 ton per 1,000 bricks. The writer was informed that tunnel kilns were in operation at one or two plants but that the maximum temp. reached in the burning zone was only about cone 12 so that the bricks were not so thoroughly burned as in the kilns.

It is the general practice to have a separate chimney to each kiln because of the greater control of the draft which is obtained and great importance is attached to the thorough cleaning out of the flues of the kiln after each burn. The heat treatment given the bricks secures the conversion to tridymite and cristobalite of a very large proportion of the quartz. The proportion of unconverted quartz varies in ordinary bricks between 25 and 45% and the volume porosity between 23 and 28 per cent. Fig. 12 is a photomicrograph of a typical Medina silica brick. The use of silica-bricks for the walls of by-product coke ovens is general throughout America. For this purpose it is obviously very important that the maximum extent of quartz conversion commercially possible should be obtained in order to avoid growth of the bricks during use. A larger proportion of lime is used (up to 3%) than in bricks for steel-making furnaces in order to promote this conversion of the quartz. The slight reduction in refractoriness thus caused is unimportant, as the thermal stability of the bricks is well above the maximum temperatures reached in the coke-oven flues. It is significant that one of the large firms of coke-oven engineers is now specifying a maximum powder specific gravity of not more than 2·35 in the silica bricks used for oven construction. Several of the large plants have a very large capacity for brick production. One plant in the

Fig. 10. Portion of Silica Brick Plant of the Harbison Walker Refractories Co., at Mount Union, Penn.

Fig. 11. Kilns at Chester, Pa. (Harbison Walker Refractories Co.)

Mount Union (Pa.) district has 19 kilns each taking 100,000 bricks and 10 taking 170,000 bricks each. The capacity of the plant is 170,000 bricks per day.

Fireclay Refractories.

The same type of plant organisation as in silica brickmaking is to be noted in the production of firebricks. Very large outputs are obtained at several of the plants and brickmaking machines are in very general use. Before the war large quantities of German clays were imported for special purposes, but equally satisfactory results are now obtained from American Clays. The refractory "flint clays" are largely used as the basis of the mixture for high grade firebricks and other articles in which high refractoriness is important. These clays are hard and break with a conchoidal fracture. They have little plasticity and are very free from impurities; the average composition approximates to Al_2O_3. $2SiO_2$. $2H_2O$. but in one or two cases, fine grained quartz is present in the clay, and increases the average SiO_2 content (see Fig. 13). In Pennsylvania these clays are mined (Fig 15), but in Missouri they occur in pockets in the limestone, the pockets varying from 50 to 200 feet in diameter and from 15 to 30 feet in depth. There is generally a few feet of sandstone between the clay and the limestone wall. This occurrence is very similar to that of the siliceous fireclays in the High Peak district of Derbyshire. In some cases the fireclay and the overlying coal are quarried, steam shovels being used (see Fig 8). A very interesting firebrick is the "Dando" ladle brick made by the McLaine Firebrick Co. at Beaver, Pa. The writer found this brick in successful use in the large steelworks, from 20 to 30 heats being obtained with large basic-steel ladles lined with this brick. Under similar conditions of use only 8 to 10 heats were obtained with high grade firebricks. This brick is made from clays of low refractoriness, the composition of the raw clays varying as follows:—

SiO_2	64 to 76	per cent.
Al_2O_3	12 ,, 23	,,
Fe_2O_3	1·5 ,, 2·5	,,
CaO	0·5 ,, 0·7	,,
MgO	0·4 ,, 1·0	,,
K_2O / Na_2O	0·8 ,, 2·5	,,
loss on ignition	5·0 ,, 7·5	,,

The refractoriness of the raw clays varies between Cones 18 and 26. The bricks are made in a modern well-planned works. The mined clays are mixed and fed into a large gyratory crusher taking 2½ to 3 tons per minute and requiring 75 h.p. to drive it. From the crusher the clay is fed into dry pans of about ½ ton capacity, the outer portion of the pan bottom being perforated. It is then screened and elevated to an agitator which keeps the clays well mixed and from this vessel the brick presses are fed. The process is a dry-

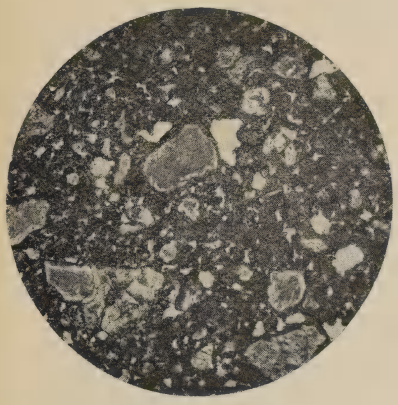


Fig. 12.

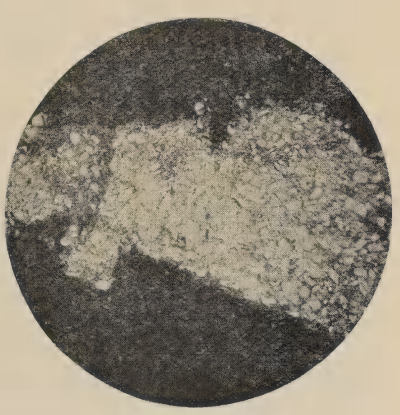


Fig. 13.

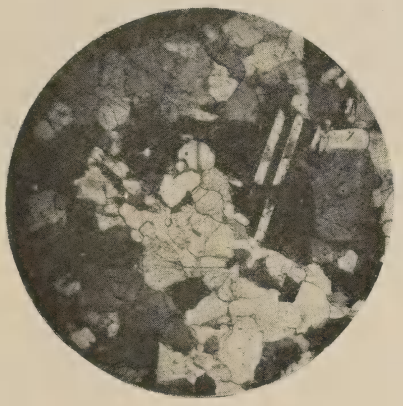


Fig. 14.

Fig. 12. "Star" Silica Brick. × 20.
Fig. 13. Quartz in Mount Savage Flint Clay. × 20.
Fig. 14. Twinned Calcite in Grenville Magnesite, between crossed nicols. × 20.

Fig. 15.

Interior of Flint Fireclay Mine at Woodland, Penn.

press one and 4 bricks are made at each operation of the press, the capacity of each press being approx. 2,000 bricks per hour. There are slots in the floor round each press through which any waste material or badly made bricks are returned by an elevator to the dry pan. The bricks are taken on cars from the presses to the kilns which are 35 feet in diameter and hold 100,000 bricks. The kilns are of an unusual type; they are down-draft but have 8 short chimneys, there being one chimney between every two-fireholes. The "smoking" period is a long one as no preliminary drying of the bricks is done, it occupies about 9 days and the burning stage proper takes 6 days, the maximum temperature reached being Cone 1. The bricks are a very good shape with dead-plane surfaces and sharp edges and the texture is dense and exceedingly uniform. In use in the steel ladle a viscous skin is formed in the first heat, there is some absorption of this viscous material into the brick and a highly resistant surface is formed. Besides the longer life of the ladle, cleaner metal is obtained by the use of this ladle brick.

For the production of glasshouse refractories (tank-blocks, pots &c.) Grossalmerode and other German clays have been, with completely satisfactory results in general, superseded by American fireclays. In making tank-blocks, pneumatic rams are used to press the tempered clay into the moulds. Potmaking practice is exactly similar to that in England but a good deal of attention is being directed to the lining of pots with a clay mixture which is more resistant to the action of the melting batch and molten glass than is the potclay itself. Additions of felspar and other fluxes are made to the clay for this purpose. The refractoriness under load of these mixtures is too low to permit of their use for building the whole wall of the pot. Casting processes for the production of pots are receiving attention and very promising results are being obtained by one large firm specialising in glass industry refractories. During the war the casting process was used by A. V. Bleininger, at the Bureau of Standards for the production of pots for melting optical glass. The pot mixture included waste pottery biscuit and fluxes in addition to the clay, the body completely vitrifying at the founding temperature. Glass industry refractories do not appear to be any higher in general quality and durability than those produced in England. On both sides of the Atlantic the use of higher melting temperatures and the making of complex glasses, which at founding temperatures are highly corrosive to fireclay, is intensifying the need for refractories which will better resist these severe conditions.

Basic Refractories. In the early stages of the war the same difficulties were experienced in America, as in other Allied Countries, with magnesite refractories as soon as the stocks of Austrian magnesite were consumed. Before the war there was a gradually increasing production of magnesite of compact (Grecian) variety

occurring on the western side of the Sierra Nevada in California. In 1913 this amounted to about 9,000 tons but in 1917 it had increased to over 200,000 tons. Crude Grecian magnesite had also been imported and the supplies of this were rapidly augmented. In addition, there was a rapid development of the spathic magnesite deposits of Washington State, over 140,000 tons being obtained from this source in 1918. The exploitation of this deposit is continuing and much larger outputs are expected (see Fig 9). In Canada the crystalline magnesites occurring in the Grenville district of Quebec were rapidly exploited, the production reached in 1917 being 65,000 tons (see Figs. 14 and 16). The stone is roughly cobbled in the quarry to remove as much as possible of the associated serpentine and dolomite. After some tribulation, methods were adopted which gave a satisfactory product from each of these raw materials and in the opinion of many users the American and Canadian sinter gives service quite as satisfactory as that obtained from the Austrian sinter. The approximate composition of these raw materials is as follows:—

	Washington.	*Californian.*	*Canadian.*
MgO	45 to 46%	42 to 46%	34-40%
CaO	0·5 ,, 2 ,,	1 ,, 3 ,,	4-10 ,,
FeO	0·2 ,, 1 ,,	0·2 ,, 3 ,,	0·2- 1 ,,
Al_2O_3	2·0 ,, 1 ,,	0·2 ,, 1 ,,	0·2- 1 ,,
SiO_2	0·5 ,, 4 ,,	1 ,, 4 ,,	1-2·5 ,,
CO_2	49 ,, 51 ,,	48 ,, 51 ,,	49-51 ,,

The magnesite is dead-burned in rotary kilns fired by powdered coal[1]. The size of these kilns varies from 60 ft. by 6ft. to 130 ft. by 9 ft. with an output of sinter of from 30 to 65 tons per 24 hours with a coal consumption of 6 to 10 cwts per ton of sinter. The crushed raw stone is in all cases mixed with a few per cent of slag, iron ore, &c., in order to reduce the sintering temperature. The approx. composition of the sinter is:—

	Washington.	*Californian.*	*Canadian.*
MgO	79-86%	75-88%	67-81%
CaO	2-4 ,,	2- 7 ,,	9-17 ,,
Fe_2O_3	4- 6 ,,	3- 6 ,,	5- 7 ,,
Al_2O_3	1- 3 ,,	1- 3 ,,	1- 2 ,,
SiO_2	4- 8 ,,	3- 9 ,,	4- 7 ,,

In the manufacture of magnesite bricks, the sintered magnesite is first of all crushed and then ground in a ball mill. It then passes into a solid bottom pan where a little water is added to it; no clay or other bonding material is added to the magnesite. Ordinary 3 in. bricks are made in a brick press producing 4 bricks at each operation of the press. Splits and other shapes are made on a hand-operated press. Larger bricks and blocks are made in wooden moulds with

[1] Crude oil is used at one plant in California, the consumption being 1 to 1⅛ barrels per ton of calcined stone—McDowell & Howe, *Amer. Cer. Soc.*, **3**, 3, 1920.

Fig. 16. Magnesite Quarry of Scottish-Canadian Magnesite Co., near Grenville, Quebec.

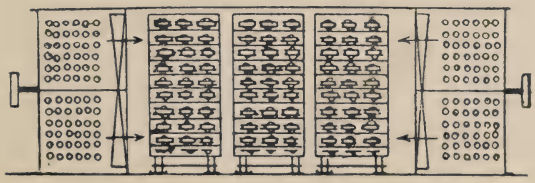


Fig. 17.

Cross-section of Dryer, showing Fans and Coils at either side.

loose liners of hard wood; the batch used is rather moister than for machine made bricks and is rammed well into the mould with a wooden rammer. The bricks are placed on cars for passage through the drying room or tunnel dryer, the hot air for drying being drawn by a low pressure exhaust fan from the cooling kilns. It was found undesirable to draw hot waste gases from burning kilns as the CO_2 present in them gave trouble. At the Harbison-Walker plant at Chester, Pa. drying crizzles have been practically abolished by the installation of a humidity dryer. This is a five-chamber dryer, the first chamber being fed with moist warm air and the succeeding chambers containing progressively drier air, that in the finishing chamber being quite dry (see Figs. 17 and 18). Drying thus takes place from the centre of the brick out-wards. All drying defects have been practically eliminated since the installation of this dryer which was designed by Messrs. Procter and Schwartz of Philadelphia. At this plant the bricks are burned in rectangular down-draught kilns with the fire holes at the corners on the shorter sides (see Fig. 11). The magnesite bricks are set in built-up compartments of silica bricks so as to avoid crushing. There are 30 kilns, each with a capacity of 30,000 bricks and the bricks are fired to Cone 18-19 in 8 to 10 days. The capacity of the plant is 40,000 magnesite or chrome bricks per day. Up till a year ago, Canadian magnesite sinter was much less satisfactory for brickmaking than for hearths but with better selection of the raw stone so as to keep down the lime content and with more thorough sintering, the difficulties have been largely overcome and satisfactory bricks are now being produced from this sinter. "Metalkase" magnesite bricks, which consist of mild steel tubes or shapes rammed full of sintered magnesite, are being very largely used in basic open-hearth furnaces and also in electric furnaces (see Fig. 19).

Dolomite. Prior to 1914 very little sintered dolomite was used in the making of basic hearths but small quantities were used for patching and fettling.

During the last few years however there has been a very considerable increase in the production and use of dolomite sinter, more particularly of specially prepared sinters to which additions of basic slag, &c., are made in order to coat the granules and increase the resistance to slaking. These special dolomites which are marketed under various special trade names such as Syndolag, Kennedymag, &c., are produced in rotary kilns fired either by powdered coal, natural gas or producer gas. The following are average compositions for the raw dolomite and prepared sinter:—

	Dolomite.		*Sinter.*
CaO	.. 28-35%	..	46-55%
MgO	.. 15-20 ,,	..	25-36 ,,
FeO	.. 0·5- 4 ,,	..	4- 8 ,, Fe_2O_3
Al_2O_3	.. 0·5- 3 ,,	..	2- 5 ,,
SiO_2	.. 1- 5 ,,	..	4-12 ,,
CO_2	.. 43-46 ,,		

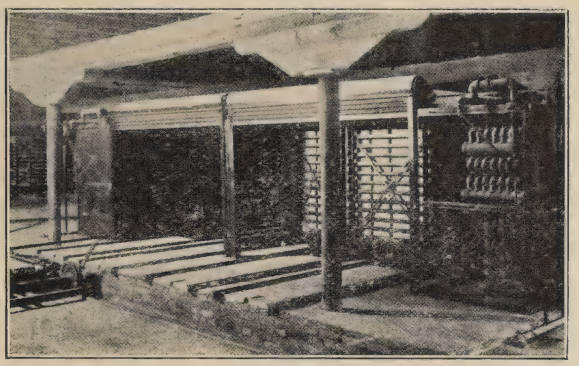


Fig. 18.

End View of Dryer with Panel on right removed to show Steam Coils.

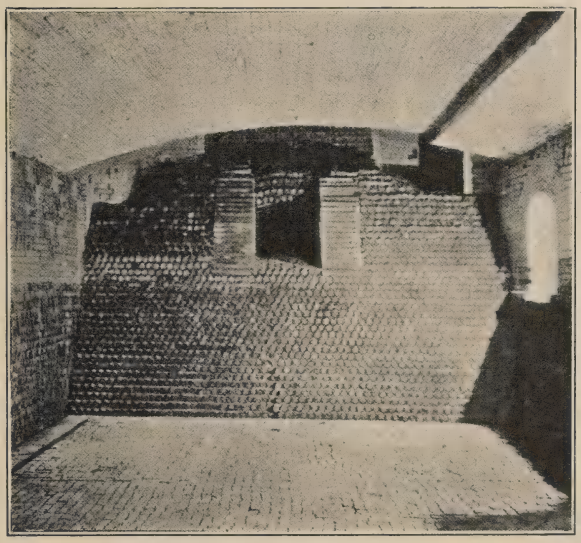


Fig. 19.

Interior of 125-ton Open-hearth Furnace lined with Metalkase Bricks.

Rotary kilns fired with powered coal are being used with considerable success for the burning of lime. The stone is crushed to about 2-in. size by a gyratory crusher before entering the kiln. A kiln 125 feet by 8 feet has an output of 80 to 90 tons of lime per 24 hours, the coal consumption being 3 to 4 cwts per ton of burned lime.

Research. The existing facilities for reseach on refractories were added to in 1917 when the Refractories Manufacturers' Association founded a multiple Fellowship in the Mellon Institute for Industrial Research (University of Pittsburgh). The main purpose of this foundation was the development of standard tests to be used in the specifications of refractories. Simple forms of test that would directly, or by inferences, indicate the probable behaviour of a refractory in actual use were desired.

Under the leadership of Mr. Raymond M. Howe, (Senior Research Fellow) considerable developments have taken place in the work. It has been recognised that in technical control of works' operations lies one of the main directions of improvement in the uniformity and quality of refractories, and facilities are provided in the laboratory for the analysis and physical testing of raw materials, partly-finished and finished materials in order that efficient methods of works' control may be evolved. The initial endowment provided was 7000 dollars per annum, but this has been considerably added to both by the Association and through payments made by individual manufacturers for special investigations. Research fellowships are also being founded by individual firms of refractories manufacturers for the study and development of refractories for special purposes. In establishing an industrial fellowship of this type, an agreement is made between the donor and the director of the Institute, in which the donor agrees to furnish a stated sum of money, the expenditure of which shall be limited to his problem and for which he shall receive an exclusive title to any results obtained[1] The Mellon Institute through this fellowship system brings into association a body of men having a wide variety of knowledge in pure and applied science and furnishes them with extraordinary facilities for augmenting and applying the same.

DISCUSSION.

Lt.-Col. C. W. Thomas:—Mr. Rees mentioned that the chief feature that appealed to him in connection with the practice of American manufacturers of refractories was the excellent layout of their plants, and the extent to which they have been able, by machinery and other means, to reduce labour. This is more than borne out by some of the photographs in Mr. Rees's possession. In one or two there is not a single man visible in the whole works. I do not know how that is managed, but the result is evidently a very successful one. One always hopes for the advent of the

[1] See *Chem. & Met. Engineering*, **22**, No. 6, 1920.

millenium, in manufacturing as in everything else. I am not sure whether Mr. Rees' remarks are a suggestion of the approach of the millenium. But when you can get good results from a Cone 18 clay, burned only to cone 4, I think there are hopes for some of us fireclay manufacturers even yet.

Mr. H. M. Ridge:—May I express my appreciation of the interesting paper with which Mr. Rees has provided us? I would like to ask him a question regarding the temperature of the humidity dryers. This method was brought to my attention some years ago and I considered its use in order to expedite the drying of zinc retorts, which, even at the present time, is still taking from 3 to 5 months. This is an extraordinarily long time to dry a piece of fireclay material, and if it were possible successfully to adopt humidity dryers for such a purpose, it would materially shorten the period required for drying. I think it is a point which is worthy of careful attention and investigation. I would like to ask Mr. Rees if he could give us any further information.

Dr. J. W. Mellor:—There is rather a holiday spirit in the atmosphere which is not conducive to serious discussion. I would like to have Mr. Rees' assurance that the drying brick is more dry in the centre than towards the outside. I can scarcely believe that such is the case, and if I saw such a brick I should assume that it had been dried and was getting wet again. Otherwise expressed, I believe a brick in that condition is not getting drier, but is getting wetter.

Mr. L. Southwood Jones:—May I ask Mr. Rees if he can give us any information as to how it is done?

Lt.-Col. C. W. Thomas:—There is no doubt that the whole secret of the manufacture of refractories at the present time is the matter of plant organisation. In face of labour troubles, increased cost of fuels, and similar problems, it is becoming imperative that the older and more out-of-date plants should be modernised, and that the very best layout that is procurable should be decided upon. I agree with the previous speaker that if Mr. Rees could see his way to discuss the matter more completely at a later meeting it would be of great advantage to the industry. Possibly this might be arranged for the next meeting. I have noticed in perusing recent publications—American and others—that much more space is being given to this aspect of things than was formerly the case. I call to mind two articles that I have seen recently giving a full description of the layout of a fireclay plant on the one hand, and a brick plant on the other, the processes in each case being largely automatic. In one case, one man, I believe, managed to do everything that was necessary for the handling of 200 tons of material per day through the grinding plant. Possibly I am less fortunate

than other members of the section, but I have yet to find a man whom one could even faintly hope to handle the grinding of 200 tons of material per day. If I could find such a man I should be inclined to lock him up lest someone else in the trade should "collar" him.

Mr. H. J. C. Johnston:—In more senses than one our present atmosphere is not very favourable towards a full discussion, but Mr. Rees in his paper has raised questions which are very interesting to firebrick makers, although he has only referred to firebrick manufacture rather briefly. To my mind the most important question is that of plant organisation. It is very obvious that if we in Great Britain are to maintain our position, something on the lines of American factory organisation will have to be attempted. Unfortunately, a large number of the firebrick makers who proposed to attend this Paris meeting have been unable to come, and I notice that many of those who are here in Paris are not present this afternoon. I think, therefore, that it might be advisable to discuss the matter somewhat more seriously with Mr. Rees at some future date. We would like to have his views, for instance, as to why a downdraught kiln 35 ft. in diameter, with 8 short chimneys, and holding 100,000 bricks, should be a better piece of plant than the continuous kilns which are at present being used in Great Britain. There are a good many points in connection with plant organisation which can hardly be dealt with except in a protracted discussion. If, therefore, Mr. Rees, on some future occasion, would give the firebrick makers an opportunity of thoroughly discussing this matter with him, I am sure it would be very useful to the trade as a whole.

Mr. Rees:—In reply to Mr. Ridge, I will obtain the temperature measurements, and communicate them to him.

With regard to Dr. Mellor's point re the drying of the brick from the centre outwards, one has to remember that the drying is not taking place in a dry atmosphere, but one that is only very slightly drier than the brick itself, Certainly in the samples that were shown to me the bricks appeared to be drier in the centre than they were towards the edges. One might talk for a long time on the possibilities of the mechanism of drying, but certainly I think that the humidity type of drier is one that should be very seriously considered by the British manufacturer of firebricks. It is a problem that is being very seriously tackled in America in connection with drying of such articles as Mr. Ridge has mentioned—retorts. One firm has already had an experimental drier installed, and is now engaged in installing a large drier for the drying of pots, which are made up to about 46 inches in size and 4 or 5 inches in thickness. I understand that pots of this size have been dried successfully in a plant of this description in a few weeks, where previously they have taken from 2 to 3 months under the most

favourable conditions. Moreover, not only is the drying expedited in this way, but floor space is very greatly economised.

In reply to Mr. Johnston, I would like, if I may, to emphasize that I am not intending to criticize unduly our English methods, but I am quite convinced, from what I saw in America, that a great deal of the success of the American manufacturer lies in the layout of his plant. The material has a proper run through. Wherever gravity can be employed, use is made of it, and consequently hand labour is very much reduced. If I can give any further information to the firebrick manufacturers with regard to the details of American plant organisation, I shall be only too pleased to do so. The kiln to which Mr. Johnston referred, with eight short chimneys was, I was informed, being utilised after numerous trials with the ordinary types of kilns, and the owners considered that, for the burning of their particular dry-pressed bricks, that type of kiln was more satisfactory than either the continuous kiln or the ordinary type of downdraught kiln with one chimney. I was surprised to learn this, but they assured me that they had carried out experiments and found it to be so.

The American works generally were not only better organised than the average works in Great Britain, but they were also freer from rubbish. One did not find lying about the works heaps of waste clay and grog. Clearly a somewhat successful attempt had been made to avoid waste owing to material lying about the plant.

Another interesting point, which I must say impressed me very considerably at the time of the American works' visits, was the very different attitude of labour towards the employer. At one plant I was astonished to find that there was a given output per day reckoned on. The normal working hours were from $7\frac{1}{2}$ to 8 hours, but if, through any untoward happening, the recognised output was not attained during the 8 hours, the men worked overtime without being specially requested to do so, in order to bring up the day's output to the normal. The men did not require asking to do this; they just did it. This was not only the case at an individual brick works, but it was almost the invariable rule in some of the sand quarries, where, of course, it is even more important than at the brickworks. The men appeared to be just as anxious to get the maximum output as was the owner. They were paid piece work and bonus.

Mr. Holland:—It would have been rather nice if Mr. Rees had brought a few of these men over with him.

Dr. J. W. Mellor:—It seems, at first sight, nonsense to say that a brick is dry in the centre and is moist near the outer surfaces. But the principle of that system of drying is not to dry suddenly, but to keep the air a little less humid than the brick itself. I think Mr. Rees will bear me out in this contention. It was a point that was worked out some years ago when using flue gases from com-

bustion chambers for drying purposes, and in course of time it gradually developed into the present system. I followed the process right through its entire development. I do not think it is quite right to say that the brick is actually drier in the centre; I simply cannot get down to the acceptance of that statement just at present. I would like Mr. Rees' own assurance that the inside of the brick is actually drier than the outside. I want to test the thing for myself, but I would like his opinion. Is Mr. Rees quite sure of the genuineness of the claim that is made, viz:— that the interior of the brick is drier, and that the dryness gradually extends to the outside?

V.—On the Nature of the Coloring Properties of Selenium Red.

By A. A. Granger, Dr. ès Sc.

As used by painters, cadmium red is a red pigment which possesses a very important advantage: it remains vermilion whereas mercury vermilion has a tendency to become darker in time. The same pigment introduced in a suitable flux gives a brilliant and beautiful enamel, especially when used for enamelling steel. Glassmakers also produce the same colour, but instead of introducing the pigment in the batch, they mix all the ingredients of the glass and colour together and melt the whole batch. The red pigment is then known by the name of selenium red.

The chemical constitution of both cadmium and selenium red is unknown. Some chemists thought the pigment was a cadmium sulphoselenide but this assertion has not been verified.

The recipes for preparing selenium red are numerous, but they consist essentially of heating materials containing: sulphur, selenium and cadmium. To provide the sulphur we may choose between the element sulphur, sodium sulphide, sodium hyposulphite or sodium sulphite. The selenium is introduced as selenium, sodium selenide or selenite or selenate and the cadmium as oxyde, carbonate or sulphide. The success of the preparation does not particularly depend on the ratio between the ingredients; it is chiefly connected with the method of heating and the temperature. To indicate a successful preparation is not easy, but a methodical chemist can succeed after a few trials.

Insufficient heating does not give the red coloration, but excessive heating produces a brown or black colour. The best method is to heat the mixture gently on a wide surface; the mixture is slowly stirred and a little is examined from time to time after cooling, because, when hot, the pigment is more brown than when cold. At about 700°C. the coloration is subject to alterations.

The examination of the pigment does not show any signs of crystallization and the want of definite proportions between the ingredients justifies the conclusion that the product is not a definite compound.

During the heating, vapours are produced and the smell of sulphur and selenium is easily perceptible. A rapid heating will cause the sulphur to ignite, and after combustion has ceased a beautiful vermilion coloration is observed wherever the sulphur had been burning. This coloration is only on the surface. If, after excessive heating the mixture is brown, some sulphur must

be added to the mixture, the whole being stirred. When the temperature is sufficiently high, the combustion of the sulphur is again observed and, as before, wherever the sulphur had been burning, a vermillion coloration develops superficially.

It is obviously difficult to study a mixture containing three components, but, selecting the ingredients, the question can be simplified. On gently heating a mixture of sulphur and selenium, the sulphur is observed to melt first and later dissolve the selenium. The mass has a strong viscosity and an extraordinarily beautiful coloration. A combination of the selenium with the sulphur is out of the question ; after cooling, the mixture is a ruby colour and has a resinous consistency. The substance is not selenium sulphide, but a solid solution of selenium in the sulphur.

Sulphur and cadmium sulphide do not give a new coloration, but the orange-yellow tint of the mixture.

A mixture of cadmium sulphide and selenium becomes red, if the heating is sufficiently prolonged. The selenium acts with the free sulphur contained in the cadmium sulphide. If the cadmium sulphide is gently roasted to eliminate the free sulphur, the reaction with the selenium is very slow, and any red coloration obtained is the result of the interaction between the selenium and the sulphur combined with the cadmium. During the heating, sulphur and selenium are vaporized and they can be condensed.

These experiments led me to conclude that the red coloration was produced by the solution of selenium in sulphur, the cadmium sulphide acting as solvent.

If my assumption is correct, other sulphides should act as solvents and give red pigments with selenium and sulphur.

I was not successful on trying yellow sulphides, as As_2S_3 and SnS_2, or red sulphides, like realgar, AsS. With ZnS a very weak coloration was observed.

Since cadmium sulphide plays a great part in producing the coloration, I tried by analysis to follow the precise transformations which occur. My results are not yet clear enough and further work is necessary before I can express an opinion.

VI.—On the Plasticity of Clays.*

Communication from the Clay and Pottery Laboratory, Stoke-on-Trent.—No. 53.

By J. W. Mellor, D.Sc.

1. Definition of Plasticity.

THE fictile qualities of a clay are primarily dependent on its plasticity. Plasticity is the property which enables a clay to change its shape without cracking when it is subjected to a deforming stress. The elasticity of the wet clay is negligibly small. Clay is peculiar in possessing another quality which is as important as plasticity. It has a high binding power when dried and fired, so that the form impressed on the plastic clay is retained more or less persistently when the clay is dried and fired. Very fine powders—barium sulphate, glass, quartz, etc.—acquire a kind of plasticity when wetted, but when dried, the binding power is exceedingly small. They are plastic but their plasticity cannot be used in the fictile arts because the second quality is wanting.

Many definitions of plasticity confuse these two distinct properties and assume that the binding power of the dried clay is implied in the term plasticity. Indeed, many methods proposed for measuring plasticity are based on the binding power of the dried clay. It is assumed that the tenacity of the dried clay is proportional to the plasticity of the wet clay. This is generally but not always true. No known property of the dried clay can be used as an infallible index of the plasticity of the wet clay, and measurements of plasticity dependent on some property of the dried clay can therefore be dismissed, because even though they may measure an important property of clay, that property is not plasticity.

2. Mechanical Analysis of Plasticity.

It is really difficult to measure the plasticity of clay because the property is somewhat complex. A Brongniart (1844) recognised its elusive character. He said: *On a souvent parlé de cette propriété, on semble la connaître, mais on n'en a qu'une vague idée.* The potter's thumb is one of the most sensitive tests at present known, but that is not always satisfactory. B. Zschokke (1903) analysed plasticity into (i) the deformability; (ii) the cohesion; (iii) the adhesion; and (iv) the viscosity or internal friction of the clay. A Martens (1898) represented plasticity, P, as being proportional to the toughness, T, of the meterial, and inversely as the modulus of rupture, R, such that $P=T/R$; H. Fischer (1884) added that the

*A *Contribution to a* General Discussion *on* "Physico-chemical Problems Relating to the Soil" *held by* The Faraday Society, *on Tuesday, May 31st,* 1921.

plasticity also varies inversely as the elasticity, e, of the material so that $P=T/eR$. These ideas resolve themselves into the assumption that

$$\text{Plasticity}=\frac{\text{Cohesion}}{\text{Internal friction}}$$

so that in estimating the plasticity of a clay, the potter's thumb is perhaps unconsciously affected by at least two effects—possibly more. There is first the internal friction which can be otherwise represented as the resistance which the clay offers to changing its shape; and second, there is the cohesion, *i.e.*, the amount of deformation which the clay can suffer without cracking. F. F. Grout (1905) worked on these lines.

Plasticity is taken to vary proportionally with each of these factors, so that if P denotes the plasticity of the wet clay, r the resistance the clay offers to changing its shape, and s the amount of deformation which the clay can suffer without cracking, then, with a and b constants,

$$P=k(r+a)(s+b)$$

where k is the constant of proportion. Each of the factors r and s can be measured and from these results P can be calculated. By a suitable choice of units, or by conventionally regarding the apparatus used in a measurement as the standard for comparison, the constant k cuts out and we can write $P=(r+a)(s+b)$.

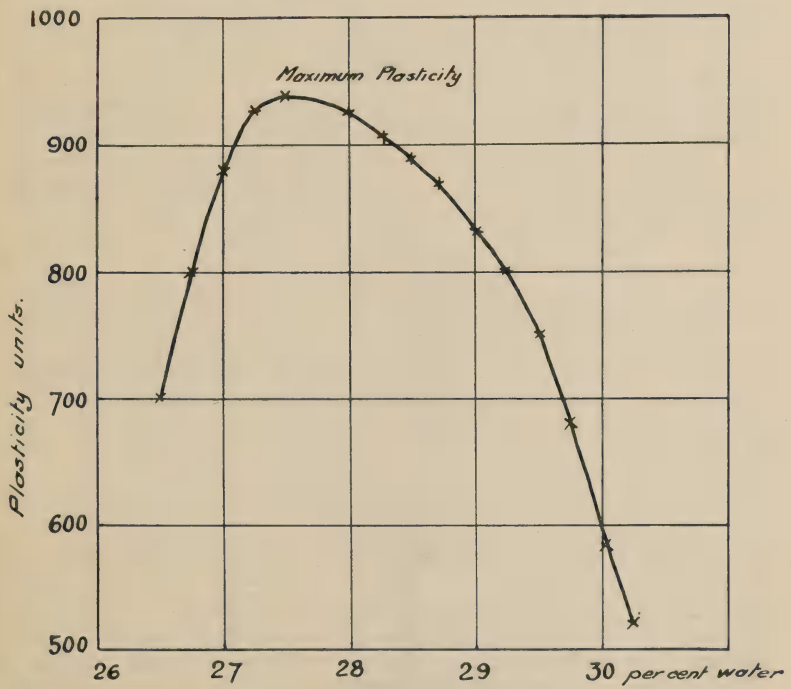
There are different qualities in plasticity. The deformation pressure of some clays is greater than others, and such clays are said to be "stiff" or "strong." Some strong clays offer a high resistance to changing their shape and yet cannot be deformed very much without cracking. In other words, the clay is "strong" and "short." Many London clays might be cited in illustration. There are other clays which have a low deformation pressure, and can suffer little deformation without rupture. Some of the siliceous pipe-clays illustrate this type of clay. They are "weak" and "short." Other "fatty" clays offer a low resistance to change of shape, and yet suffer a comparatively large deformation without rupture. The black ball clays show this quality.

3. The Measurement of Plasticity.

The plasticity of a clay varies with the proportion of water in a curious way. As water is progressively added to a dry clay, the plasticity continually increases and attains a maximum value. Any further addition of water reduces the plasticity; the clay assumes another form. The particles no longer have a marked tendency to cohere together, rather does the clay become "sticky," and it adheres to anything it touches which water can "wet." In the sticky stage the clay is no longer workable. As more and more water is added, the clay assumes the form of slip, and can then be poured like a liquid.

It is therefore interesting to measure the relations between the proportion of water in the clay and the resistance the clay offers to changing its shape, and the deformation the clay can suffer without cracking. The results give two curves, $r=f(w)$, and $s=f'(w)$, and when the data are substituted in the equation $P=f(w).f'(w)$, they give a curve, Fig. 1, which simulates the observed phenomena by showing that the plasticity increases up to a maximum with increasing proportions of water. It is difficult to get concordant measurements, and the following method of measurement is not satisfactory, but it represents the present stage of the work of Messrs. G. E. Stringer and W. Emery which will be published later.

A sphere of the clay mixture is made 2 cm. in diameter. This is difficult. Messrs. G. E. Stringer and W. Emery gave a lot of attention to this subject in 1913, and their final mould was arranged as in Fig. 2. It represents an ordinary metal mould fitted with small spring cylinders *ss*, which release the sphere from the mould in which it has been pressed.



Plasticity Curve of Ball Clay.

Fig. 1.

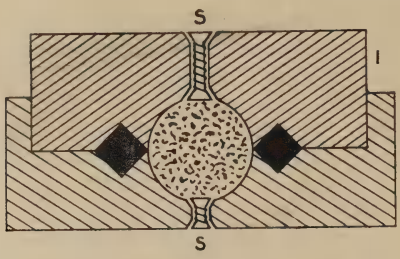


Fig. 2.

Cylindrical test pieces were not so satisfactory as the spherical ones. The sphere was placed about the centre of a weighed glass-slab and weighed. The glass-plate and sphere were then placed at *A* in the machine illustrated in Fig. 3. The disc *A* is adjusted until it just touches the sphere, and its position noted on the index *I*. Sufficient fine shot is run into the bucket *B*, to make the piston descend. The descent of the piston is stopped when vertical cracks appear on the edges of the clay disc. The mirror *M* allows the back of the disc to be readily seen. The distance moved by the descending piston is taken to represent the amount of deformation the clay could suffer without cracking ; and the weight of the bucket of shot required to compress the clay spheres a definite distance is taken to represent the resistance the clay offered to changing its shape. The glass slab and clay disc are dried at 110° and the loss in weight allowed the percentage of moisture in the original clay to be calculated.

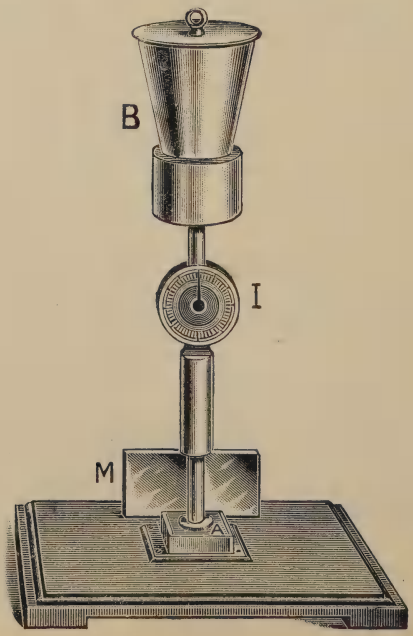


Fig. 3.

4. The Effect of Pressure on the Maximum Plasticity.

The state of maximum plasticity represents the best working condition for the clay, but that is so near the state of stickiness that, to allow a safe working margin, the clay should be worked with a little less water. Another point, the greater the moulding pressure applied to the clay, the smaller the proportion of water required to develop maximum plasticity, and the smaller the proportion of water required to make the clay sticky.

TABLE I.

Maximum Plasticity of Wet Clay Developed at Different Pressures.

Pressure, Kgrms. per Sq. Cm.	Water, Per Cent.
200	5·6
150	8·8
100	12·5
50	19·2
25	23·0
1	26·4

This point is easily tested by subjecting wet clay to different pressures and observing the pressure at which the clay sticks to the tool. With an earthenware body mixture the sticky stage developed at the pressures shown in Table I. when the clay contained the proportions of water indicated. This is rather an important consideration in preparing clays to be worked by machine process.

5. The Physical Analysis of Plasticity.

Plasticity is a mechanical property, the resultant effect of a deformation and a pressure. The deformability of a clay is probably determined by the distances the particles can move without loss of cohesion ; and the deformation pressure represents the magnitude of the cohesive or attractive forces as shown by the resistance offered by cohesion to the movements of the particles under the influence of an impressed force. The deformability of the clay is then conditioned by the size and shapes of the particles ; and the deformation pressure is determined by the magnitude of the cohesion between the clay particles and the water, and by the thickness of the water film.

Until it has been shown that plasticity is a definite function of some other quality—dye-absorbing property, viscosity of slip, etc.—it cannot be assumed without reservations that measurements of these qualities measure plasticity. The claims made on behalf of such indexes of plasticity are arguments in a circle. Take the dye-absorbing test which I used in 1905. Plasticity is assumed to vary with the amount of colloid in a clay ; the amount of colloid

in the clay is then assumed to be proportional to the amount of dye the clay can absorb from a standard solution. Hence, dye-absorption measures plasticity. Obviously, a lot of work has to be done before this can be accepted. The viscosity test is in exactly the same condition.

Some methods which have been proposed for measuring plasticity really measure only one of the two components—deformation and pressure—into which plasticity has been resolved. For example, the so-called Vicat's needle test, A, Brongniart's wad-box test (1844), P. Jochum's bending test (1899), and K. Dummler's spiral test (1908), ultimately measure deformation, not pressure; and they give comparable results under constant conditions for a particular type of clay when the pressure is constant, but not necessarily so for different types of clay.

6, Plasticity and Colloidal Clay.

The plasticity of a clay is often assumed to be inversely proportional to the grain-size. H. E. Ashley (1909), for example, made this an essential part of his formula. The observation has been qualitatively recognised for a couple of centuries. A. Baumé in his *Mémoire sur les argilles ou recherches et expériences chymiques et physiques sur la nature des terres les plus propres à l'agriculture* (Paris, 1770) attributed the high plasticity of clays to their extremely fine state of subdivision, and to their containing some saline matter. He said:

> On doit attribuer le liant des argilles à l'extrême division de leurs parties qui les rend propres à retenir l'eau, et à leur état salin qui leur donne la faculté d'être presque dissolubles dans l'eau. Leurs molécules sont beaucoup plus dans l'état de division, que celui qu'on pourroit procurer à une pierre quelconque par des moyens méchaniques. On peut bien donner au sable et à toutes les matières vitrifiables beaucoup de liant en les réduisant en poudre impalpable sur le porphyre; mais quelque divisées que soient ces substances, elles ne peuvent jamais acquérir le liant des argilles, parcequ'elles n'ont rien de salin qui les rende miscibles à l'eau; les argilles elles-mêmes n'ont presque plus de liant lorsqu'on leur a enlevé leur acide, quoique la substance terreuse reste dans le plus grand état de devision.

If A. Baumé's *état salin* be translated "matter in a colloidal state," then his paragraph might have been written to-day. The meaning is clear; superposed on the plasticity exhibited by fine-grained powders, clays have a plasticity in virtue of their contained saline or colloidal matter. A. Baumé thus approximates to the assumption made by T. Way in 1850, T. Schlösing in 1870, P. Rohland in 1902, and by H. E. Ashley in 1909, that plasticity is proportional to the amount of colloidal matter in the clay—*l'argile colloïdale* of T. Schlösing—and inversely as the state of subdivision. If, as appears highly probable, the plasticity of clay is proportional to the amount of colloidal matter in the clay, the dye-absorption test is probably invalid because there is nothing to show that the colloidal matters in different clays have the same absorption power. It is fairly certain that the colloidal matter in different clays

is—say ball clay and china clay—not the same, for this must be largely determined by the nature of the organic matters associated with the clay at the time of its deposition, or which have been afterwards acquired from extraneous sources.

Clays have qualities which might be predicted from the known properties of matter in the colloidal state. It is therefore assumed that clays contain x per cent. of colloidal matter possessing qualities like those possessed by the clay itself. This explanation recalls A. Baumé's *saline matter*, and the *terra pingua* of the mediæval chemists. The plasticity of clay has been attributed to both these imaginary substances. Indeed, just as in mediæval times every chemical process which was not understood was explained by an assumed *terra pingua*, or phlogiston, so now, we are inclined to attribute to the colloids every quality of clay which is not understood. Nevertheless, I believe a modified colloidal hypothesis gives the best working explanation of several properties of clay, even though it must be added that we have not progressed very far in advance of the eighteenth century. Calling the same thing different names is not getting along very fast.

7. Plasticity and the Grain-size of Clays.

The evidence for the statement that plasticity is inversely proportional to grain-size is not to be accepted without reservations. B. Zschokke (1903), and F. F. Grout (1905) have both shown that the plasticity of some clays is not influenced by finer grinding, and that the plasticity of other clays is lessened by fine grinding. This shows that close packing is also concerned in the action. It follows that closer packing is possible with mixed fine and coarse grains than with all fine or all coarse grains, and U. Aleksiejeff and P. A. Cremiatschensky (1896) have shown that both extremely fine-grained and extremely coarse-grained clays are less plastic than clays containing mixed fine and coarse grains. Hence, if grinding makes the particles more uniform in size, the clay will become less plastic; and it is probable that, other things being equal, the distribution of grain-sizes which permits the closest packing of the particles, will be most favourable to high plasticity.

8. The Effect of Acids, Alkalies, and Salts on the Sedimentation of Clay.

Plasticity *per se* can be readily explained by the known properties of films of water, and theories have been devised which postulate special shapes for the predominant particles in the clay, *e.g.*, H. le Chatelier (1910) postulated flattened particles; and W. Olzschewsky (1880) spongy particles. There are, however, a number of cognate properties possessed by wet clays which are of assistance in the clarification of our concept of plasticity. For example, the slow development of plasticity during the weathering or ageing of clays; the action on clay-slip of alkalies, hydrolysable

salts, acids, and certain organic compounds like tannin ; the high tenacity of dried clays, etc.

The facts connected with the action of alkalies, etc., on clay-slip have been worked out by many investigations on the sedimentation of clay, etc., suspended in water. It has been observed that there are three classes of substances concerned in these effects:—

I. *Flocculation.*—Acids, acid salts, lime, calcium sulphate, sodium chloride, and most neutral salts cause the fine particles in suspension to flocculate or coagulate into groups and settle; these agents also enhance the plasticity of clays.

II. *De-flocculation.*—A small proportion of ammonia, alkali hydroxide, alkali carbonate, borate, silicate, or a salt of other weak acids deflocculate, de-coagulate, or peptise the clay causing it to assume a more finely divided condition than in water, and thus remain in suspension for a longer period. These agents also diminish the plasticity of clays.

III. An excess of the deflocculating agents may produce the converse effect giving the same result as if an acid had been added.

The attractive forces exerted on the molecule at the surface of a liquid are smaller than on a molecule in the interior so that there is a tendency for the surface molecules to move inwards. The general result is that the surface tends to contract as as to leave the smallest number of molecules on the surface. K. Fuchs (1889), M. Whitney (1892), and W. J. A. Bliss (1895) have pointed out that with fine-grained particles of a solid suspended in a liquid there are two cases :—

(1) The molecules of the solid attract those of the liquid more strongly than they attract one another and more strongly than the molecules of the liquid attract one another. In that case the water film about the particles will tend to enlarge, and the grains will not come together, but rather be held apart. The system will be in equilibrium when each particle of the solid is surrounded by a shell of liquid nearly the same thickness as the radius of intermolecular attractive forces. The particles will then repel one another if brought closer together than twice the radius of the molecular force. This corresponds with the phenomenon of deflocculation.

(2) If the attractive force of the liquid for the liquid is greater than that of the solid for the liquid, the particles will tend to approach closely to one another. Otherwise expressed, the fine-grained particles of the suspended solid will flocculate.

The effect of alkalies is to keep the clay particles apart, the effect of acids is to make them form aggregates. The result is rather remarkable. Clay-slip prepared with about 0·3 per cent. of a mixture of sodium carbonate and silicate, can be readily poured in casting operations, and yet it contains less water than a stiff mass of clay without the alkali. The addition of a little acid to the former so as to neutralise the alkali is attended by an immediate "solidification" of the slip. The vessel can then be turned upside

down without interfering with the contents. The addition of more alkali will again make the slip pour readily. These properties are extensively utilised in the Ceramic Industries.

Let F_{sl} denote the attractive force of the solid for the liquid and F_{ll} that of liquid for liquid, then flocculation or de-flocculation, will occur according as $F_{sl}-F_{ll}=F$ is negative or positive. If F decreases there is an increasing tendency to flocculation. The gravitational attraction of the particles for one another may be assumed constant so that when a change is made in the composition of the liquid, by the introduction of dC parts of a solute, $\frac{dF}{dC}$ will be negative when a trace of a flocculating substance (Class I.) is added; and positive when a trace of a deflocculating substance (Class II). is added. $\frac{dF}{dC}$ changes sign for substances in which there is a reversal of the effect when increasing proportions of the solute are added (Class III). In all cases therefore $\frac{d^2F}{dC^2}$ is negative

Attempts to evaluate F_{ll}, the attraction of two unit masses of a solution have been made by S. D. Poisson (1831), P. Volkmann (1882), O. E. Meyer (1861), W. J. A. Bliss (1895), and W. Sutherland (1893); and the effect has been studied by D. Berthelot (1898), and B. Galitzine (1890). J. J. Thomson (1888) showed that the value of F_{ll} is probably slightly greater near the solid than in the same portion of the solution further away, and is different from the value at the boundary surface between the liquid and air. Consequently, F_{sl} may be qualitatively but is not quantitatively proportional to the surface tension of the liquid. The value of F_{sl}, the attraction of unit mass each of solid and liquid, has not been determined experimentally, although W. J. A. Bliss suggested an expression analogous to that employed for F_{ss}.

To summarise, when the molecular attraction of the liquid for the liquid predominates over that of the clay for the liquid, the shell of liquid about the clay will diminish, and flocculation will set in. This case is characterised by acids and substances of Class I. When the molecular attraction of the clay for the liquid predominates over that of liquid for liquid, the shell of liquid about the clay will enlarge, and the grains of clay will be kept apart and deflocculation will occur. This case is typical of dilute solutions of the alkalies, and substances of Class II. The behaviour of substances in Class III. shows that there is a critical concentration below which the molecular attraction of clay for the liquid predominates, and above which the attraction of liquid for liquid is predominant. The gravitational attraction of solid for solid has been neglected because it can be regarded as a constant under these conditions. L. Wolf (1906) has built an explanation on the assumption that the particles of clay attract one another according to the gravitational

law; but any other assumed law of attraction would apply equally well, or rather equally unsatisfactorily.

The hypothesis just indicated shows how the plasticity of a clay can increase with increasing proportions of water so long as the average thickness of the surface films of water on the particle of clay is not greater than the average range of the molecular attraction of the clay for water. When enough water has been added to produce thicker films, part of the water will be outside the range of this attraction, and the clay will be less coherent, and become "sticky."

The high molecular attraction of clay for water is illustrated by the magnitude of the Pouillet effect. With approximately the same surface area, the maximum effect with china clay is nearly 1·50 cals. per gram; 0·03 cals. with ground quartz; and 0·01 cals. with ground flint. Attempts by J. Aron, B. Kosmann, etc., to refer plasticity to the hydration of the clay molecules have not been very successful because no direct relation has been observed between the plasticity and the water of hydration *per se*. It is, however, noticeable that the greater the plasticity of the clay, the greater the proportion of water required to develop maximum plasticity. Thus a highly plastic clay may take up 30 per cent. of water before becoming sticky, while less plastic clay requires 20 per cent., and a short clay may become sticky after 10 per cent. of water has been added.

In analysing the effect of acids, bases, and salts on clays, it is necessary to take adsorption into consideration. The relation of the clay particles to the liquid may be drastically modified when the clay particles contain adsorbed salts, acids, etc. This, however, does not affect the qualitative explanation of the effects just outlined; nor is it necessary to make any assumption as to the nature of the attractive forces.

9. The Action of Colloidal Matter on Clay.

The remarkable effects of gum and other mucilages in enhancing the plasticity of clay has been utilised by potters for an indefinitely long time. In 1903, E. C. Acheson patented the use of aqueous solutions of the tannins and gallotannins, *e.g.*, decoctions of oak-bark, etc.; and in 1918 G. Keppler and A. Spangenberg patented the use of decoctions of humic acid, peat, etc. These plasticising agents probably act indirectly by adsorption. The clay particles adsorb the organic colloid, and judging by results this probably lessens F_{sl}, the molecular attraction between the particles and the surrounding liquid. The plasticity of china clays, practically free from organic matter, shows that adsorbed organic colloids are not the source of their plasticity.

Clays which have been sodden with ground waters rich in organic matter are usually highly plastic; and those clays which can be shown geologically to have been deposited in swamps and bogs, or which have been in contact with such waters, are always

plastic unless other metamorphic changes have occurred. Many such clays, however, are not plastic when freshly dug, but they become plastic during weathering. When first mined some of the clays are hard, but if they be moistened and exposed to sunshine and frost they more or less quickly disintegrate and crumble to fine-grained plastic clays.

Clays which are allowed to stand for a long time in contact with moisture become more plastic, or, as the workmen express it, more "buttery." Clays which have been boiled with water also become more plastic. Clays prepared by fast processes—filter-press—are not so "buttery" as when prepared by a slower process—slip-kiln. China clays prepared by the elaborate, apparently primitive Cornish process are more plastic than when the process of de-watering the clay is accelerated by filter-press. There is thus an intimate connection between the plasticity of a clay and its past history with respect to water. All this looks as if the clay is being hydrated to form a colloid.

Attempts have been made to establish the colloidal theory of plasticity by adding artificially prepared colloids to feebly plastic clays. A. S. Cushman (1902), for example, found that when colloidal silica is added to such a clay, the air shrinkage and the tensile strength of the clay are increased, but not the plasticity; but with colloidal alumina, neither the air shrinkage nor the tensile strength were increased but the plasticity was augmented. F. F. Grout, however, pointed out that unlike the plasticity of clays, the plasticity acquired by the addition of colloidal alumina is lost when the clay is dried. Similar remarks apply to the colloids prepared by precipitation from a mixed solution of alum and water glass. If the plasticity of clays is due to the presence of a colloidal aluminosilicate, it is therefore necessary to assume that it is due to a form which has not yet been recognised. S. Kasai (1896) could find no colloidal clay in Zettlitz china clay.

10. Attempts to Isolate L'Argile Colloïde.

If clay, freed from soluble salts, be boiled with water and allowed to stand 24 hours, extremely finely-grained particles of solid will remain in suspension an indefinitely long time. The suspended clay can be isolated by evaporation, or by the addition of a trace of sodium chloride, lime-water, etc., which rapidly precipitates the suspended clay. The finest particles are invisible with a $\frac{1}{12}$-inch objective. The stuff obtained by evaporating the "clear" liquid from ball clay, is a deep brown, hard, horny mass resembling glue. It adheres tenaciously to the tongue, and, like glue, it swells enormously when wetted with water, and the wet sticky mass shrinks enormously and cracks when dried. Cornish china clay gave about 0·005 per cent. Devonshire ball clays about 0·05 per cent. It is doubtful if this product represents all the colloidal matter in these clays. Obviously the method of isolation

would miss any colloidal matter which might be present as a coating on other grains. No difference could be detected in the plasticity of the clay from which *l'argile colloïde* had been removed. The properties of this colloidal matter simulate in a highly exaggerated form the behaviour of clays on drying, and I am inclined to think that the colloid plays an important part in the drying of clay. I cannot see that the "felting" action of the particles of the drying clay is an adequate explanation of the comparatively high tenacity of dried clays. The impermeability of wet puddled clay to water is also difficult to understand on the "felting" hypothesis.

APPENDIX to § 7.

THE CLOSE AND OPEN PACKING OF SPHERICAL GRAINS.

It is often stated that the porosity of finely ground material is of necessity smaller than that of coarsely ground material. It is so essential to have clear ideas on this subject that a little arithmetic may not be out of place, particularly when the statement just cited is usually correct, but is sometimes wrong.

In the first approximation, and for the sake of simplicity, consider the case of spheres of uniform dimensions. These spheres may be packed in two ways subject to the condition that each sphere is always in contact with its immediate neighbours. The first is typified by Fig. 1, and the second by Fig. 2. These diagrams represent the foundation layer; subsequent layers are superposed in accord with the basal plan.

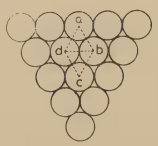


Fig. 1.
Close Packing.

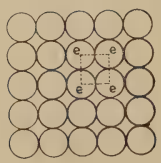


Fig. 2.
Open Packing.

To show (i) that the porosity of a mass of spherical grains of uniform size is independent of the size of grain; and (ii) that the more uniform the size of grain the greater the porosity:

For close packing, each sphere rests between the neighbouring spheres so that planes through the centre of the contiguous spheres of radius r form an equiangular triangle—angles 60°; similarly, the centres of four contiguous spheres form the apices of a tetrahedron with edge $2r$. Since the base is a square, the edge with n spheres in the side is $2nr$. The cubical content of the tetrahedron is therefore $(2rn)^3/3\sqrt{2}$. The volume of n such spheres packed in a tetragonal pyramid is

$$\left(\frac{4}{3}\pi r^3\right)\frac{n^3}{3}; \text{ or } \frac{4}{9}\pi r^3 n^3$$

The volume of the pores is the difference between the volume of the pyramid and of the spheres.

$$\frac{(2rn)^3}{3\sqrt{2}} - \frac{4}{9}\pi r^3 n^3 = \frac{4r^3n^3}{9\sqrt{2}}(6 - \sqrt{2}\pi)$$

Consequently, the ratio of the pore volume to the total volume of the pyramid is

$$\frac{\frac{4r^3n^3(6-\sqrt{2})}{9\sqrt{2}}}{\frac{8r^3n^3}{3\sqrt{2}}} = \frac{6-\sqrt{2}}{6} = 0{\cdot}2593$$

Hence, *the minimum porosity with contiguous spheres closely packed is* 25·93 *per cent.*

For loose packing, the volume of the cube is $(2nr)^3$; and the volume of the spheres is $\frac{4}{3}\pi n^3 r^3$; therefore

$$\text{Volume of pores} = 8n^3r^3 - \tfrac{4}{3}\pi n^3 r^3; \text{ or } \tfrac{4}{3}n^3r^3(6-\pi).$$

The porosity is therefore the ratio of the pore volume to the total volume of the cube, that is

$$\frac{\frac{4}{3}n^3r^3(6-\pi)}{8n^3r^3} = \frac{6-\pi}{6} = 0{\cdot}4762.$$

Hence *the maximum porosity with contiguous spheres openly packed is* 47·62 *per cent.*

It will be observed that these results are quite independent of the radius, and apply to spheres of any diameter provided they are all the same size. Hence, the porosity is independent of the size of the grains. In the case of spheres of different sizes, where the smaller spheres can be packed in the spaces between the larger spheres, the pore space may be diminished. It follows then that the more nearly alike the grains are in size, the greater the pore space with a given type of packing, provided the smaller particles can be packed in the interstices. It also follows that where the particles are angular and not spherical a closer packing is possible.

VII.—The De-hydration of Dried Clays.

By J. W. Mellor, N. Sinclair and P. S. Devereux.

It is generally supposed that clay retains its combined water up to about 500°, and J. W. Mellor and A. D. Holdcroft (1912) showed that if the heating be conducted *in vacuo*, the water commences to be slowly evolved at much lower temperature, even before 300°. E. Löwenstein (1909) showed that if clay be kept for some time at 25° over sulphuric acid, part of the so-called combined water in clay: $Al_2O_3 . 2SiO_2 . 2H_2O$, is lost. N. Sinclair repeated these experiments about 1910, and P. S. Devereux about 1914. The experiments were interrupted by war-work.

Finely powdered samples of clay were dried over 25 per cent. sulphuric acid, and placed in desiccators containing sulphuric acid of different concentrations. The desiccator and contents were kept in a bath at a constant temperature of 25°. The samples were weighed every week until the readings appeared constant. The time occupied was approximately three months. If years were available, possibly more water would be lost by the clay. The different samples of sulphuric acid employed are indicated in Table I.

Table I.

Vapour Pressure of Aqueous Solutions of Sulphuric Acid at 25°.

Per Cent. H_2SO_4.	Vapour Pressure
30	18·0
40	13·5
50	8·8
60	4·3
70	1·8
80	0·6
90	0·0

The following tables contain the observed results. Table II. is by Mr. Norman Sinclair, and Table III. by Mr. P. S. Devereux.

Table II.

Percentage Loss in Weight on Exposure of Different Clays in Dried Atmospheres.

Per Cent. H_2SO_4	Halloysite	Pyrophillite	Wetley Marl
30	1·72	+·04	·76
40	8·68	·00	2·00
50	10·36	·20	1·32
60	11·40	·12	2·60
70	11·52	·24	2·80
80	12·52	·20	3·08
90	11·84	·40	3·20

The + symbol means that there is an increase in weight with

the more dilute solutions of sulphuric acid. This is due to the adsorption of moisture. There is also evidence of a slight adsorption of a sulphur oxide with the more concentrated sulphuric acid.

Table III.

PERCENTAGE LOSS IN WEIGHT ON EXPOSURE OF DIFFERENT CLAYS IN DRIED ATMOSPHERES.

Per Cent. H_2SO_4	Ball Clay	China Clay	Glen-boig Clay	Halloy-site	Kaolin-ite	China Clay	Halloy-site
30	0·08	0·16	0·09	0·10	0·06	0·01	0·06
40	0·24	0·12	0·11	0·41	0·08	0·06	0·44
50	1·63	0·20	0·30	0·93	0·12	0·13	1·67
60	2·31	0·24	0·48	1·84	0·18	0·16	1·96
70	2·44	0·46	0·67	1·92	0·24	0·23	3·26
80	3·29	0·52	1·12	2·37	0·38	0·36	3·62
90	3·54	0·55	1·48	2·58	0·46	0·50	4·05

The three determinations of halloysite show different results, probably due to part of the assumed halloysite being china clay. The numbers for kaolinite refer to a well-crystallised sample from Glamorganshire investigated in another direction by J. W. Mellor and A. D. Holdcroft (1912). The results for ball clay, china clay, and one of the samples of halloysite are plotted in Fig. 4.

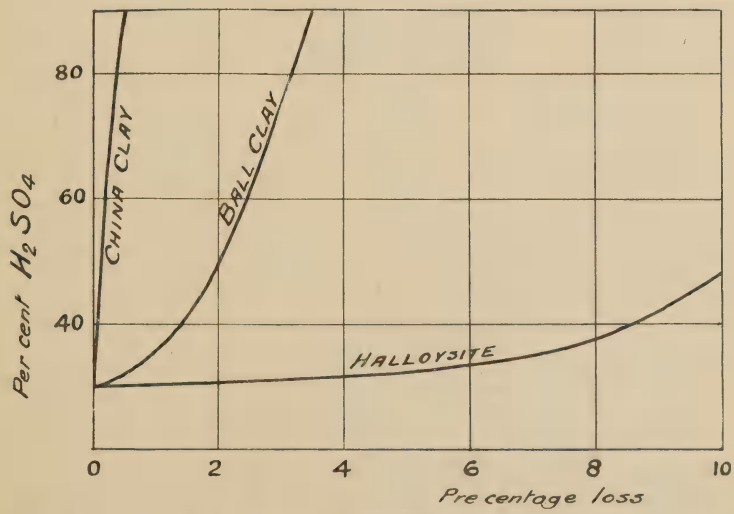


Fig. 4. Loss in Weight of Clay when Confined over Sulphuric Acid of Different Concentrations at 25°.

E. Löwenstein's observations are thus confirmed. Clays gradually lose some of their so-called combined water at ordinary temperatures. This water is reversible and is restored in a moist atmosphere, thus showing that no drastic change has occurred in the structure of the clay molecule. This change is totally different from that which occurs when water is expelled at the higher tmeperatures. E. Löwenstein believes that only one-fourth of the combined water is so expelled, but the action is so slow that this statement may require modification.

This over-dried clay, if such a term is applicable, has some important properties. The resorption of water is so very slow and it requires such a long time to restore the original plasticity, that the working qualitites—plasticity, shrinkage, etc.—of certain troublesome clays can be mollified and regulated by desiccation. Mr. Bernard Moore tells us that this is a time-honoured custom in some branches of pottery manufacture and the subject has been discussed by A. V. Bleininger (1910). The dried clay approaches the condition of many unweathered fireclays in requiring exposure to a moist atmosphere for a long time before the original plastic condition is resumed. The custom of seasoning glass pots for a few months in a warm dry place may not really be so redundant an operation as might at first sight be supposed. From this point of view the storing of clays in a warm dry spot is not conducive to their subsequent working in their most plastic state.

VIII.—Notes on Jointing Materials for Refractories.

Communication from the Clay and Pottery Laboratory, Stoke-on-Trent.—No. 100.

By Dr. L. Bradshaw and W. Emery.

I.—The Softening-Point of Mixtures of Silica Brick and Clay Firebrick.

In general, the jointing material used for laying fireclay bricks consists of a mixture of ground raw clay and grog, with or without sand, while for silica bricks, crushed silica with a small proportion of fireclay is employed. It is well known that the softening temperature of silica fireclay mixtures is lower than that of either constituent. Where the reduction of refractoriness is only slight, it may be an advantage, as, for instance, in cases where the partial vitrification of the jointing material strengthens its binding power; but beyond a certain point, any increase in the fusibility of the bond is undesirable. It is, therefore, important to determine experimentally to what extent the softening point of fireclays is affected by the addition of increasing quantities of siliceous material or *vice versa*; and the need for such data has been suggested to us by Dr. J. W. Mellor. Seger[1] has constructed a curve showing the fusion points of pure silica mixed with pure alumina, and with kaolin. The present experiments relate to mixtures of crushed silica brick with fireclay brick.

The materials, after grinding, were found by analysis to have the following chemical composition and grain size (Table I):

Table I.—Chemical Analysis and Grain Size.

	Silica Brick	Fireclay Brick
SiO_2	96·02	56·78
TiO_2	Trace	1·38
Al_2O_3	0·96	37·35
Fe_2O_3	0·79	2·37
MnO	—	—
MgO	0·11	Trace
CaO	1·18	0·74
K_2O	0·26	0·60
Na_2O	0·26	0·68
Loss on ignition	0·20	0·38
Through 200's lawn	99 p.ct.	82 p.ct.

It will be observed that practically the whole of the silica and over 80 p.ct. of the fireclay pass through a 200's lawn. This degree of

[1] H. Seger: "Collected Writings," p, 545

fineness is sufficient to ensure an intimate admixture of the two substances.

The mixture was formed into cones of suitable size, and the refractoriness determined in the usual way in an electrically heated furnace. As a check upon the results, three or four of the test-pieces in sequence were mounted on the same base and heated together, whereby an indication of their relative order of softening was obtained, apart from the reading of the Seger cones adjacent to them. The results are tabulated below (Table II.) and plotted in the curves (p. 109).

TABLE II.—NORMAL REFRACTORINESS OF MIXTURES OF FIRECLAY BRICK WITH SILICA BRICK.

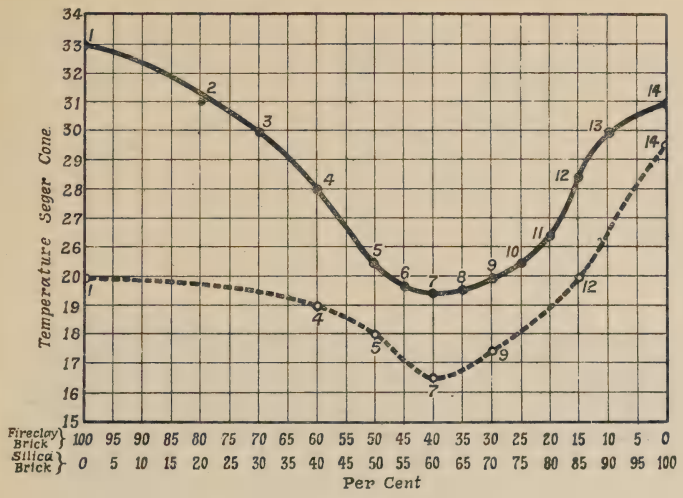
No.	Fireclay Brick	Silica Brick	Normal Refractoriness Seger Cone
1	100	..	33
2	80	20	31
3	70	30	30
4	60	40	28
5	50	50	20–26
6	45	55	19–20, nearer 20
7	40	60	19–20
8	35	65	20, softer than No. 9.
9	30	70	20
10	25	75	20–26
11	20	80	26–27
12	15	85	28–29
13	10	90	30
14	—	100	31

It will be seen that the addition of a small amount of fireclay to silica brick produces a greater effect than a corresponding amount of silica brick added to fireclay brick. Thus, the addition of 25 p.ct. of fireclay to silica brick (Experiment 11) reduces the refractoriness by $4\frac{1}{2}$ cones and of about 43 p.ct. (Experiment 9) by 6 cones ; while the addition of these amounts of silica brick to fireclay brick (Experiment 2 or 3) produces differences of 2 cones and 3 cones respectively. The eutectic mixture, which softens at Seger cone 19–20, has the composition 15·01 p.ct. Al_2O_3, 80·32 p.ct. SiO_2—corresponding to 1 molecule Al_2O_3 ; 9 molecules SiO_2. For pure kaolin and silica mixtures, Seger obtained an eutectic having the approximate composition 1 Al_2O_3 : 17 SiO_2, which softened at cone 26. It should be noted, however, that the silica and fireclay bricks contain bases, by which the eutectic point is greatly influenced.[2]

The general form of the curve (p. 109) corresponds to that obtained by Seger.

A few of the above mixtures were also submitted to a refractory

[2] G. Flach, Sprechsaal Kaer, 1913.



test under load ; and results were obtained as shown in Table III.

These results are plotted in the broken curve. The values fall into the same order as those of the ordinary refractoriness, but the curve is steeper on the silica side and flatter on the fireclay side—*i.e.*, the differences between the softening temperatures with and without load are less in the case of siliceous mixtures than for mixtures rich in fireclay, thus confirming the results by Mellor, Moore, and Emery.[3]

Table III—Refractoriness under Load of Mixtures of Fireclay Brick with Silica Brick.

No.	Fireclay Brick	Silica Brick	Refractoriness under Load 35 lbs. per Sq. In.
1	100	—	20
4	60	40	19
5	50	50	18
7	40	60	16·17
9	30	70	17·18
12	15	85	20
14	—	100	29·30

When coarser grained mixtures are substituted for those used in the foregoing experiments, the effect upon the softening point is less marked. Thus the softening point of a mixture consisting of equal parts of fireclay (normal refractoriness cone 33) and building sand (normal refractoriness cone 32) was found to be cone

[3] J. W. Mellor and B. J. Moore, *Trans. Cer. Soc.* **15**, 117, 1916. J. W. Mellor and W. Emery, *ibid*, **15**, 360, 1917,

30–31 ; those of mixtures containing 33·3 p.ct. and 80 p.ct. of the same sand, cones 30 and 29 respectively. The grain sizes and chemical composition of the clay and sand are shown in Table IV.

TABLE IV.—CHEMICAL ANALYSIS AND GRAIN SIZE OF THE FIRECLAY AND BUILDING SAND.

	Fireclay	Building Sand
SiO_2	49·72	87·12
TiO_2	1·21	0·19
Ai_2O_3	32·72	5·18
Fe_2O_3	2·07	2·03
MnO	—	—
MgO	trace	0·02
CaO	0·63	1·30
K_2O	0·52	2·04
Na_2O	0·57	0·8
Loss on ignition	12·66	1·34
Residue on 20's mesh	—	10·5
Through 20's on 40's	33·3	23·0
,, 40's on 80's	33·3	54·2
,, 80's	33·3	12·3

In this case the cones were made-up with raw fireclay and tested after firing once at a low temperature. It is probable, however, that the softening point of the coarser mixtures would be further reduced in actual use, owing to the gradual disintegration of the silica grains.

II.—MIXTURES OF FIRECLAY WITH FIRECLAY GROG.

In the preparation of mortars for fireclay bricks, the addition of grog to fireclay is a general practice. Grog is added to lessen the shrinkage of the clay. On the other hand, it reduces the binding power and mechanical strength, and the mixture is more difficult to spread. The grading and proportioning of the materials used are of prime importance ; but these factors do not appear to have received much attention.

In the following experiments, the effects of mixing carefully graded materials in various proportions have been studied. The materials employed had the following composition :—

TABLE I.—CHEMICAL ANALYSIS OF FIRECLAY AND GROG.

	Raw Fireclay	Grog
SiO_2	49·72	56·76
TiO_2	1·21	1·38
Al_2O_3	32·72	37·35
Fe_2O_3	2·07	2·37
MnO	—	—
MgO	trace	trace
CaO	0·63	0·74
K_2O	0·52	0·60
Na_2O	0·58	0·68
Loss on ignition	12·66	0·38
Refractoriness, Seger Cone	33	33

The clay and grog were used in three grades:

(*a*) Coarse	Through 20's mesh on 40's	
(*b*) Medium	,, 40's ,,	80's
(*c*) Fine	,, 80's ,,	

The wet mixture, of suitable consistency, were spread between a pair of fireclay bricks, which were then keyed together by slabs of the same material let into grooves in the ends. After allowing to dry for several days, they were fired in an industrial kiln at a maximum temperature of cone 8. In all cases, the joints were practically of equal thickness. The general appearance of some of these joints is shown in figs. 1 and 2.

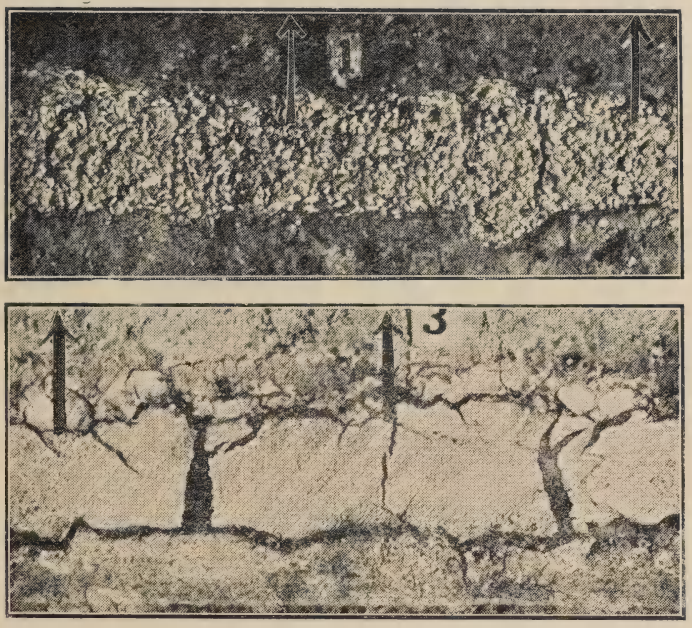


Fig. 1—Joints showing Transverse Cracking. The Vertical Arrow-Headed Lines are 1 inch apart on the Material.

When the material has a high contraction, cracks develop during the air-drying, while in other cases they appear only after firing. These cracks (figs. 1 and 2—Nos. 1, 3 and 12) are invariably transverse—*i.e.*, across the joint—owing to the shrinkage along its length. Longitudinal cracks generally do not appear.

The method adopted for locking the bricks has the disadvantage that the upper brick is prevented from sinking as the mortar contracts, as it would do if built into masonry; and for this reason a fine parting (see fig. 2, No. 11) is sometimes observed along the face of the brick. Since, however, certain mixtures possess very little binding power, the bricks in such cases tend to fall away when

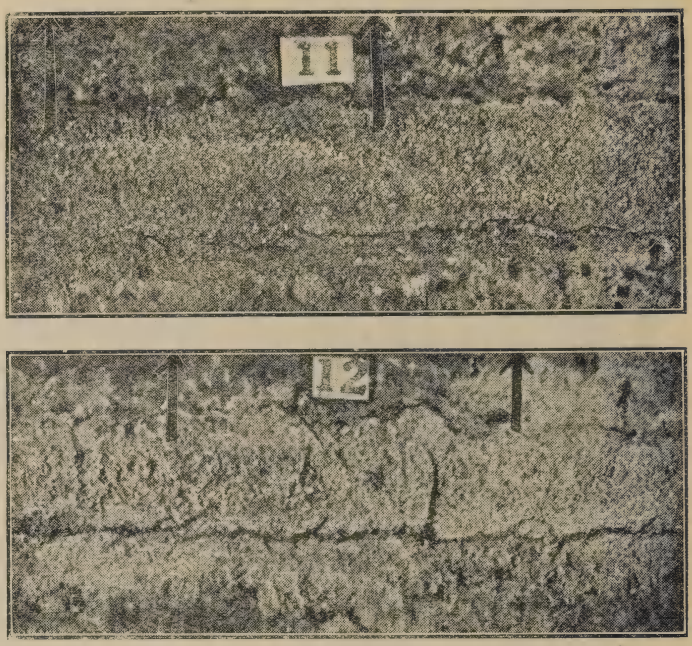


Fig. 2—No. 11 Shows Fine Longitudinal Parting between Brick and Jointing Material. The Vertical Arrow-Headed Lines are 1 inch apart on the Material.

they are turned on edge for the slag penetration tests, and some method of holding them together is essential. This fact should be borne in mind in examining the data obtained in the slag penetration tests. The longitudinal parting, which is often so fine as to escape detection except under a magnifying glass, would probably not occur in bricks built into columns and free to settle under their own weight.

For the measurement of contraction and resistance to crushing, the mixtures were formed into briquettes. The examination of the material in mass in this way affords useful information as to the relative properties of the various mixtures; but the data thus obtained are not a safe criterion of the suitability of such mixtures for jointing purposes, except in so far as they are used in conjunction with other observations. A briquette of fine clay, for example, forms a hard compact mass free from cracks, which offers very high resistance to crushing and slag penetration. The same clay, after firing between bricks, exhibits large fissures into which slag can penetrate freely. The use of briquettes in the slag penetration test, however, is essential, as it affords the only means of determining the penetration into the material proper, as distinct from the flow

TABLE II.

Experiment No.	Composition: Fireclay Coarse.	Fireclay Medium.	Fireclay Fine.	Grog Coarse.	Grog Medium.	Grog Fine	Contraction: Wet to Dry P.Ct.	Contraction: Dry to Fired P.Ct.	Contraction: Total	Crushing Strength of Briquettes, Lbs. per Sq. In.	Relative Slag Penetration, * No. 3 = Unit. Briquettes.	Relative Slag Penetration, * No. 3 = Unit. Joints	Observations on Jointing-Material after Firing.
1	1	–	–	–	–	–	2·0	4·5	6·5	830	26	In cracks	Very friable, fine transverse cracks
2	–	1	–	–	–	–	7·5	5·8	13·0	6,000	4	Along parting	Friable, free from cracks, fine longitudinal parting
3	–	–	1	–	–	–	10·5	6·7	16·5	13,600	1*	In cracks	Very hard, large transverse cracks
4	1	–	–	1	–	–	None	—	—	< 400	30	40 and along parting	Friable, free from cracks, fine parting
5	–	1	–	1	–	–	1·0	1·0	2·0	1,070	20	12	,, ,, ,, ,,
6	–	–	1	1	–	–	5·0	1·0	6·0	3,200	8	In cracks	Firm, fine local cracks
7	1	–	–	–	1	–	0·5	0·5	1·0	< 400	28	32	Very friable, free from cracks
8	–	1	–	–	1	–	2·5	1·5	4·0	1,280	12	22	Firm, free from cracks
9	–	–	1	–	1	–	5·0	1·0	6·0	3,500	5	In cracks	Firm and hard, fine local cracks
10	1	–	–	–	–	1	1·5	0·5	2·0	730	16	16	Friable, free from cracks
11	–	1	–	–	–	1	2·0	1·0	3·0	1,800	9	9 and in cracks	Firm, a few local cracks, fine parting
12	–	–	1	–	–	1	5·5	1·0	6·5	3,500?	6	12 and in cracks	Firm and hard, extensive fine cracks, fine parting
13	–	–	2	–	–	1	5·5	2·0	7·5	5,210	5	8 and in cracks	,, ,, ,, large transverse cracks
14	–	2	–	–	–	1	3·5	2·0	5·5	2,860	6	6 and in cracks	,, ,, ,, ,, ,, ,, ,, better than 13
15	–	–	2	–	1	–	5·5	2·0	7·5	6,630	6	—	Firm, very hard, large transverse cracks
16	–	2	–	–	1	–	3·5	1·7	5·2	2,200	7	8	Firm, hard, free from cracks
17	–	–	1	–	–	2	3·0	1·2	4·2	2,960	2	6 and in cracks	Firm, a few transverse cracks
18	–	1	–	–	–	2	2·5	1·0	3·5	1,710	4	8 and in parting	Firm, less hard than 17, free from cracks, fine parting
19	–	–	1	–	2	–	3·0	1·0	4·0	3,070	6	6	Firm and hard, free from cracks
20	–	1	–	–	2	–	2·5	0·9	3·4	< 800	10	10	,, ,, ,, ,, ,,
21	–	–	1	–	–	3	2·9	1·1	4·0	2,730	8	10 and in cracks	Firm, fine transverse cracks
22	1	1	1	1	1	1	3·1	0·9	4·0	2,230	7	6 and in parting	Very hard, free from cracks, slight parting
23	1	1	1	2	2	2	2·0	0·2	2·2	1,560	8	8 and in parting	,, ,, ,, ,, ,, ,, ,,
24	2	2	2	1	1	1	5·5	1·0	6·5	2,500	8	8 and in parting	Firm, and hard, moderate transverse cracks
				Sand Ungraded									
25	1	1	1	3			4·9	0·6	5·5	1,300	10	16	Soft and friable, free from cracks
26	2	2	2	3			6·3	1·0	7·3	2,170	9	10 and in cracks	,, ,, ,, moderate transverse cracks

of the slag into cracks. This test is described in the Appendix. The results obtained are collected in Table II. The sharp increase in the contraction of the clay with diminishing grain size is clearly shown, as also the corresponding increase in mechanical strength ;[4] and the resistance to slag penetration (experiments 1, 2, and 3).

The addition of 50 p.ct. of grog of the same grade (experiments 4, 8, and 12) largely reduces the contraction, and allows a greater penetration of slag. Differences of the same kind but of less magnitude are obtained by the use of only 33 p.ct. of grog (experiments 16 and 13). The effects of a larger proportion of grog are shown in experiments 20 and 17.

Other experiments show the effects of mixing different grades of clay and grog. A briquette of fine clay with coarse grog (experiment 6) has a much greater contraction and crushing strength, and suffers less slag penetration in the mass than a mixture of coarse clay with fine grog (experiment 10). While mixture 10 is friable, 6 is firm, this being due to the binding power of the clay between the grog particles.

The influence of fine clay on the wet-to-dry shrinkage is very marked (experiments 6, 9, and 12). In comparing these experiments, it may be noticed that the values obtained differ but slightly, and that the effect of increasing the grain size of the grog is not clearly brought out. In reality the differences are probably somewhat greater; but they are masked by experimental error, due to the difficulty of making accurate measurements of the contraction of the coarser-grained mixtures. Errors of at least 0·5 p.ct. may be expected. Taken as approximations, however, the figures give a satisfactory indication of the general effects.

Of the mixtures examined, those composed of mixed grades of clay and grog (Nos. 22 and 23) appear to give the best results. These mixtures are mechanically strong, have a sufficiently small contraction, and set between bricks to a hard, compact mass, which is free from cracks and is not easily attacked by molten slags. They might probably be improved by omitting the coarse grade of clay and grog, and would be worth examining in greater detail. No. 24, in which the proportion of clay is increased, is not so good.

The effect of substituting ungraded building sand (for analysis, see Table III.) for grog, is shown in Nos. 25 and 26, which are generally inferior to Nos. 22 and 23.

The addition of sand diminishes the fire-shrinkage, but renders the mixture friable. It seems likely, however, that the addition of a small proportion of fine silica to mixtures of clay and grog would be beneficial for several reasons. Experiments on these lines will form the subject of a later report.

It is evident that the preparation of a suitable mortar is mainly a question of balancing the opposing quantities of its constituents.

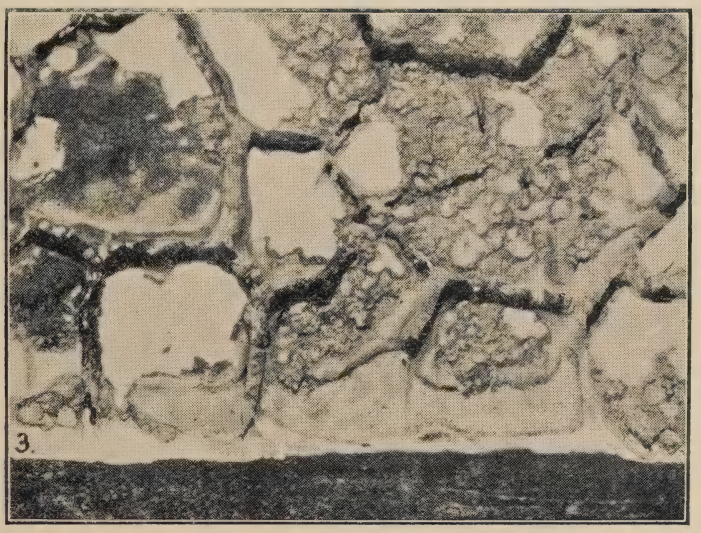
[4] For the effect of grain size on crushing-strength see J. W. Mellor and W. Emery, *Trans. Institution Gas. Eng*, 1918-9, p. 378.

Fire clay alone, in mass, is not readily affected by corrosive slag; but in joints, owing to the extensive cracking, the slag penetrates

TABLE III.—CHEMICAL AND MECHANICAL ANALYSIS OF THE BUILDING SAND.

SiO_2	87·12
TiO_2	0·19
Al_2O_3	5·18
Fe_2O_3	2·03
MnO	—
MgO	0·02
CaO	1·30
K_2O	2·04
Na_2O	0·8
Loss on ignition	1·34
Residue on 20's mesh	10·5
Through 20's on 40's	23·0
,, 40's on 80's	54·2
,, 80's	12·3

deeply into the network of fissures, whereby a much larger area of material is laid open to attack (see Fig. 3). The addition of grog reduces the shrinkage and cracking, but increases the porosity and decreases the mechanical strength of the material, and so on.



(Englarged three times),
Fig. 3.—Horizontal Face of Mortar after Removing the Upper Brick Showing Penetration of Slag into Network of Cracks. (Section at Right Angles to Face of Joint).

The influence of the addition to fireclay of various substances such as Portland cement, lime, asbestos, sodium silicate, carborundum, &c., has been studied by R. M. Howe.[5]

Appendix.

The slag penetration test is based upon that of Messrs. Nesbitt and Bell.[6] A rectangular porcelain trough $1\frac{1}{4}$ in. in depth is placed horizontally over the joint and cemented to the bricks. It is then filled with a mixture of a fusible, corrosive mixture. On heating to a high temperature, the slag attacks the jointing-material and generally also the brick. The amount of penetration will obviously depend upon the specific corrosive power of the mixture employed, as also upon the duration of heating and the temperature.

The results obtained by this method are merely comparative. In the experiments recorded above, the penetration into fine clay (No. 3) is taken as unity, and the other values represent the average depth of penetration—not the area, which is sometimes taken. When the material develops cracks, the penetration into the substance proper is frequently obscured by the flow of slag through the cracks. In any case it is difficult to measure the penetration with accuracy; and the values given are intended merely to serve as a rough guide.

The mixture in the trough had the following composition: Litharge, 43 pct.; sodium carbonate, 40 p.ct.; sodium fluosilicate, 13 p.ct.; and ferric oxide, 4 p.ct.

[5] Raymond M. Howe, *Chem. Met. Eng.*, 23, 232, 1920; *Gas Journ.*, Feb. 17, 1920

[6] C. E. Nesbitt and M. L. Bell, *Proc. Amer. Soc. Test. Mat.*, 18 ii. p. 345, 1918.

IX.—The Influence of Oxidizing and Reducing Atmospheres on Refractory Materials.

Communication from the Clay and Pottery Laboratory, Stoke-on-Trent.—No. 101.

Part I—.The Behaviour of Clay Pyroscopes and Fireclay Bricks in Coal-Gas.

By Dr. L. Bradshaw and W. Emery.

During the course of some experiments in which pyrometric cones, used to indicate the temperature of refractory test-pieces heated electrically in a tube furnace, were exposed to a current of coal gas, we observed that the cones remained erect at temperatures far above their normal softening points. On subsequent examination, some of these cones were found to consist merely of a hollow shell with a quantity of slag discharged at the base, or of a semi-vitrified mass covered with an infusible skin. The outer shell is extremely refractory. In view of the fact that, under works conditions, pyrometric cones are frequently exposed to reducing atmospheres of coal gas and air, the closer investigation of their behaviour in such circumstances appeared to be of interest, since any irregularity would vitiate the conclusions deducted from the cone data.

The cones may be conveniently examined in groups. R. Rieke[1] studied the effect of heating Seger cones 022-15 under various conditions in air. He found that the melting-points of all these cones are influenced by the rate and duration of heating—thus confirming the earlier observations of J. W. Mellor[2] that time and atmosphere are essential factors in the action of heat on Seger cones. Cones 022 to about 013a melt at a lower temperature when the rate of heating is slow—in consequence of their relatively high content of easily fusible frit—while cones 012a to 1a show the reverse effect, in that, on prolonged heating, they undergo a sort of devitrification on the surface, whereby a more refractory skin is formed which supports the whole mass. The formation of this skin is attributed to various causes, such as: (1) The production of refractory silicates (or alumino-silicates) by the gradual interaction of the individual constituents. (2) The partial escape of the more volatile constituents on prolonged heating. Boric acid and the alkali borates especially tend to volatilize, the effect of this being to lower the proportion of fritting substance in the surface layer and thus to produce a less fusible shell on the outside

[1] R. Rieke, *Keram. Rundsch.* **19**, 549, 1911.
[2] J. W. Mellor, *Staffordshire Weekly Sentinel*, May 20, 1905, and *Trans. Cer. Soc.* **7**, 79, 1910.

of the cone[3]. (3) The oxides present in the cone-mixture (especially ferric oxide contained in cones 010-1) may, under the solvent action of the boric acid, form large crystals, which react but slowly with the mass.

Rieke submitted cones 08a-1a to a prolonged heating in a porcelain furnace at cone 09a. After this treatment, the cones exhibited a matt, devitrified surface. On heating them beside the corresponding original cones in an experimental electric furnace, it was found that the treated cones retained their sharp edges and matt appearance after bending, while the others have a smooth surface and rounded edges. The softening point of the treated cones was 15° to 40°C. higher than that of the original cones. The contrast in the appearance of the cones observed by Rieke is illustrated in fig. 1, where specimens taken from a local porcelain kiln after several hours slow heating are shown together with the corresponding cones fired more rapidly. The normal appearance of the cones

Fig. 1.

is seen in the middle of the plate. We have prepared these specimens from English made cones 08-010, which do not contain any iron oxide. Further, Rieke found that the range of cones 2a to 17

[3] Compare A. F. Hottinger, *J. Amer. Cer. Soc.* **3**, 183, 1902; the effect is said to be due to the expulsion of boric acid from the cone mixture by the sulphurous fuel gases and also to the formation of calcium sulphate.

soften at a lower temperature on protracted heating than on rapid heating. Cones 6-9 exhibited differences amounting to as much as 80° to 100°C.[4] This is supposed to be due to the high viscosity of the vitrified mass by which the bending is retarded.

The effects which we have obtained by heating Seger cones in coal gas cannot be accounted for by any of these explanations, since they are observed not only in the lower cones containing borax frit, but also in the higher ranges of cones which are free from borax and other volatile matter. Moreover, the rate of heating adopted in these experiments is comparatively rapid, generally approximating to 10°C. per minute.

C. Loeser[5] compared the behaviours of Seger cones in oxidizing and in reducing atmospheres, and noted important differences in the appearance of the residues. Cones 021-016, on heating to a sufficiently high temperature in an oxidizing atmosphere, melted-down to a smooth glass containing black specks of organic matter, while in a reducing atmosphere the residues consisted of sharply pointed pyramids of uniform deep colour or black throughout. He remarks: "Since we cannot assume that the composition of the lower portion and the interior of these cones originally differed from that of the tip and the outer coat, this appearance can only be explained by supposing that the relatively higher rate of heating in the reducing atmosphere brings about a partial separation of the constituents, the more fusible portion running out." We shall return to this point later. Many years ago, a writer in the "British Clayworker"[6] called attention to the abnormal behaviour of cones (apparently in a brick kiln). Despite the usual precautions taken to protect them from the direct flame and dust, "what appeared to be a perfect cone, looked at through the inspection hole, has turned out to be nothing but the shell of a cone, the inside having fused and run-out at the bottom." Our experiments have shown that this is the normal behaviour of a wide range of Seger cones[7] when heated in coal gas, or in mixtures of coal gas with a limited amount of air, to a temperature well above their ordinary softening points. It appears to be due to the formation of a thin film of hard carbon in intimate contact with the surface of the cone.

Bone and Coward[8] who investigated the thermal decomposition of a number of hydrocarbons, found that this variety of carbon is produced by the decomposition of methane. "The carbon deposited from methane is of a peculiarly hard and lustrous type, wholly different from the dull and soft variety yielded by the other three hydrocarbons (ethane, ethylene, and acetylene) except in so far as part of the latter may arise as a result of the secondary decomposi-

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[4] Compare Hoffmann, *Tonind, Ztg*, **35**, 1099, 1911.

[5] Loeser's *Ber. für Keramik*, **19**, 111-206, 1910.

[6] *British Clayworker*, Aug., 1898, p. 140.

[7] The cones used in these experiments are of English manufacture. Similar results were obtained with some cones of German origin supplied by Seger and Cramer, Berlin.

[8] W. A. Bone and H. F. Coward, *Jour. Chem. Soc.* **93**, 1197, 1901.

tion of the other hydrocarbons mentioned." Since all these hydrocarbons may be present in coal gas, their mode of decomposition on heating has an important bearing on our subject. Bone and Coward showed that not only is methane the most stable of the above-named hydrocarbons, but it is always a principal product of the decomposition of the other three—especially at temperatures above 800°C. Methane itself decomposes for the most part directly into carbon and hydrogen. The process of decomposition was found to differ from those of the other hydrocarbons in that it is wholly a surface effect; the carbon being deposited on the walls of the furnace-tube and the fragments of unglazed porcelain packing, in the lustrous metallic form already referred to. Methane remains practically unchanged up to about 800°C. Between 800° and 1,000°C. it decomposes slowly, but only in contact with hot surfaces. Above 1,000°C. its decomposition, while still entirely a surface effect, is more rapid. In the case of the other three hydrocarbons, decomposition takes place throughout the entire body of the gas and proceeds rapidly at temperatures above 800°C. For this reason coal gas generated in retorts where the coal is carbonized at temperatures of 800°C. and upwards contains comparatively little ethylene and ethane, and practically no acetylene.[9] The coal gas used in the experiments described below contains approximately 32 p.ct. of methane and less than 2 p.ct. of other hydrocarbons. Both types of carbon are obtained, but the lustrous variety predominates and appears to be the main cause of the increased refractoriness of the cones. In the case of cones which do not soften below about 1,000°C., the temperature of the furnace can be raised to upwards of 800°C. before admitting the coal gas. Under these conditions, an inappreciable amount of soft carbon is deposited, and the surface of the cones exhibits a beautiful metallic lustre. A similar effect is obtained when pure methane is substituted for coal gas.

The apparatus employed is an electrically heated tube-furnace of the Hirsch type, consisting of a central vertical tube of highly refractory material within an outer case of fireclay, the space between the two being filled with powdered graphite. The current passes between a pair of ring electrodes placed at the top and bottom of the graphite column. For the purpose of these experiments we introduced a slight modification, which we have found convenient in the general investigation of the action of gases on refractory materials at high temperatures. This consists of a second cylindrical tube placed co-axially within the first. In the ordinary single tube furnace, a considerable amount of carbon monoxide is usually formed from the oxidation of the graphite by air diffusing through the porous walls of the tube. This can be greatly diminished by the arrangement of double tubes. The space between

[9] Bone: *Coal and its Scientific Uses*, London, 1908, p, 131.

the tubes is swept out with a current of inert gas (such as nitrogen), while the test-piece is exposed in the inner tube to an atmosphere relatively free from impurities. The gases enter through two nozzles screwed into a water cooled plate which forms an air-tight joint at the bottom of the furnace. In the present case two independent currents of coal gas are used. It should be observed that the coal gas is in no way intended for the heating of the furnace.

The appearance of some of the cones taken from the furnace is shown in fig. 2. The superficial crust is plainly distinguishable

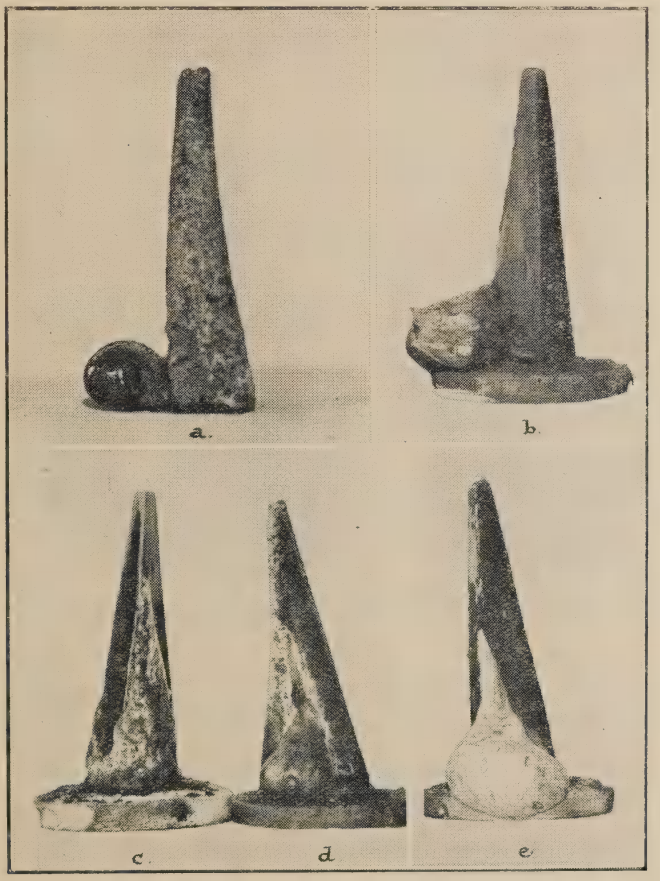


Fig 2.

in (*c*), where it is seen split down the edge and forced outward by the slag. The heating was interrupted at this stage. In (*e*) is shown the effect of further heating on a similar cone. In (*d*) the

slag has been discharged at a weak spot on the face of the cone. The lustrous grey shell is best observed in (*a*). All these specimens were prepared from cone 10 (normal softening point about 1,300°C.).

A large number of cones having different softening points were tested, and the same effects were noted in the more refractory cones. In the downward direction, as might be expected, a limit is reached approximately at the temperature at which the decomposition of methane almost ceases. A firm, refractory shell can be produced with certainty down to about 950°C. (cone 08a). Below this temperature the results become erratic, while lower

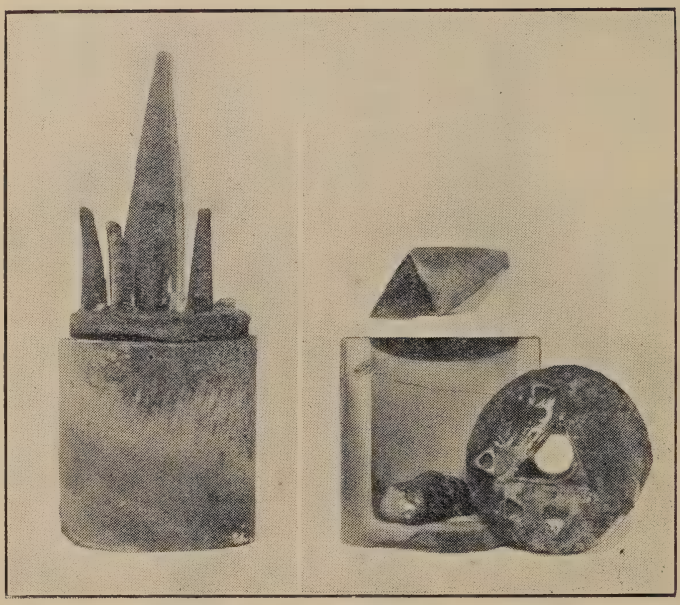


Fig. 3.

still the cones are only slightly affected. The softening points of the low cones are raised slightly above the normal, and the residues are found to be impregnated with carbon. This offers a probable explanation of the refractory stumps obtained by Loeser in the experiment referred to above, where a slight excess of coal gas was present.

The carbon is not confined to the surface of the cones, but is found in the pore spaces throughout the mass. Cones ordinarily contain traces of organic matter from the binding substances used in their preparation, but this may be completely removed by gentle ignition in air. A microsection[10] through a cone ignited in this way

[10] We are indebted to Dr. A. Scott for preparing the microsections.

and then heated in coal gas for a few minutes at about 1,000°C. shows the cavities lined or completely blocked-up with carbon. There is no evidence of the formation of carbides. Carbon is also found enclosed in the slag from the interior of the cone, but in insufficient quantity to produce a very marked elevation of the softening point.

It has been found possible, by a simple arrangement, to drain off the slag from the interior, leaving the outer shell intact. The cone is mounted over a hole of suitable size bored through a thin refractory plate which forms the lid of a hollow cylinder of the same material. On heating in a current of coal gas to a temperature considerably above the normal softening point of the cone, the viscous material is discharged into the receptacle below, while the refractory shell remains standing and appears from the outside unaltered. Fig. 3 shows a cone (cone 10) after heating in this way to 1,650°C. above its normal softening point). On the left the cone is seen, surrounded by a number of smaller specimens, standing upright as removed from the furnace ; while to the right, it is shown broken through, exposing the hollow interior. Part of the cylinder has been cut away to show the slag residue.

Note on the Behaviour of Fireclay Brick in Coal-Gas.

A few experiments were made with test pieces of fireclay brick heated in an atmosphere of coal gas under the conditions already described. The surface deposition of hard carbon is also observed in this case ; but the temperature attained in the furnace, in general, is not sufficiently high to reduce the clay material to a mobile slag.

Test-pieces prepared from fireclay mixed with a small percentage of ferruginous marl, by which the softening point is lowered, behave similarly to cones, the slag bursting through the coating of carbon. This is illustrated in fig. 4. In (*a*) is shown the slag partially discharged through two vertical cracks ; in (*b*), the shell has been broken at the top to show the hollow space beneath.

The idea of a protective coating of hard carbon artificially produced on fireclay surfaces might possibly be utilized in gas-works practice.

Note by the Director, Dr. J. W. Mellor.

There are many features about the action of reducing gases on ferruginous clays which have puzzled me for years. I thought that it would therefore be well to start from the beginning and commence with clays as free from combined iron as nature has supplied. Seger cones offered convenient mixtures for this purpose.

The experimental result indicated in fig. 4 is extraordinary, and the experiment itself is ingenious.

There are some important lessons to be learned from the results here set forth.

Fig. 4.—Full Size.

(1) The fusibility of the mixture itself is not much affected by the reducing atmosphere *per se*.

(2) In the presence of hydrocarbons, the gas decomposes and deposits a hard variety of carbon in the shell. This is a totally different thing from the result claimed in the patent by R. Lessing, No. 12,119 (1911).

The carbon deposited in Dr. Bradshaw's and Mr. Emery's work is not the ordinary smoke variety, but is of a hard, presumably graphitic form. The graphitic carbon is also more intimately associated with the clay, when deposited by the decomposition of the gas, than when a mixture of clay and graphite is used as a refractory.

At present the imparted refractoriness is a surface effect, but the refractoriness of the shell is so very much higher than that of the untreated material that if the fact can be applied practically, it should be possible to make a super-refractory from the purer clays (and with bricks also from ordinary fireclays). Even if we succeeded in thus augmenting the refractoriness of the bricks in a practical way, we should be far from a complete solution, because the imparted refractoriness might not endure under working conditions. It is therefore best to drop speculations and try.

X.—Closed Circuit Grinding.

By J. C. Farrant.

THE object of this paper is to obtain the views of those interested in the Pottery Trade with regard to the continuous closed circuit system of grinding.

The following suggestion appeared in the October 1st, 1920, issue of the "Brick and Pottery Trades Journal," written by the Author :—

"Grinding in Ball Mills."

"Referring to Mr. L. Brown's remarks upon ball milling, published in your issue of June 1st, the following question arises : Why should not continuous closed circuit grinding be more generally employed in the pottery trade, as in other industries ? The advantages of such a system are :—

1. Greater tonnage per horse-power.
2. Reduction of labour costs.
3. Continuous Operation.
4. Lower consumption of grinding media.

Grinding in batches necessitates periodical hand charging and dumping, with consequent loss of time during these operations. Further, in order to reduce every particle to the required fineness, *an enormous amount of time is wasted in grinding material already fine enough.*

Batch grinding has been superseded by continuous closed circuit grinding in preparing for paint manufacture, silica, phosphates, felspar, etc., for use in various industries. The system of closed circuit grinding applies both to wet and dry reduction. A series of open and closed circuit grinding tests to minus 200's lawn have recently been carried out on a very extensive scale on the Mesabi Range iron ores. A diagrammatic illustration of the wet grinding method in close circuit employed in these tests is shown below :—

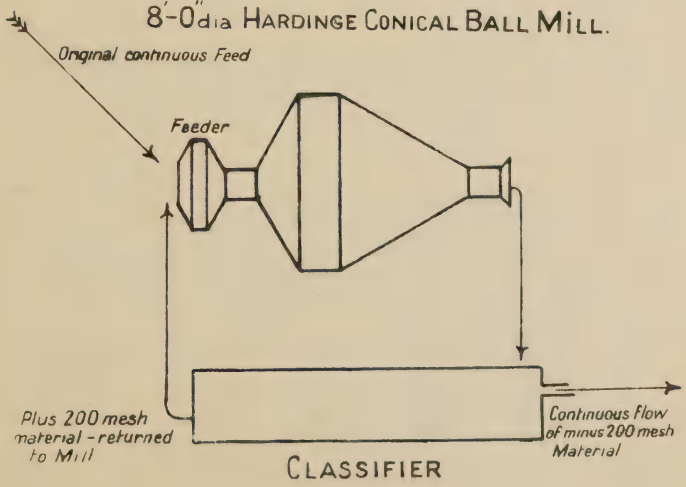

8'-0" dia Hardinge Conical Ball Mill.
Original continuous Feed
Feeder
Plus 200 mesh material - returned to Mill
Continuous flow of minus 200 mesh Material
Classifier

Fig. 1.

The illustration shows a product of 200's lawn (·063 mm.) material continually flowing from the classifier. The fineness of the product is in proportion to the amount fed to the mill, but is also subject to adjustments made to the classifier and the amount of water used. The most important points for efficient closed circuit grinding are :—

1. Regular feed.
2. Correct ratio of water to material (wet method).
3. Sizes of grinding media.
4. Speed of Mill.

It would be interesting to learn the views of those engaged in the pottery trade concerning the above method."

The publication of this suggestion led to a request to read a short paper on the details of closed circuit grinding in practice.

The following details of operation and figures are extracts from a paper read before the American Institute of Mining Engineers by Mr. E. W. Davis, in February, 1919 :—Before proceeding to give the actual working figures, a short description of closed circuit grinding is given for the benefit of those who are unfamiliar with it. The Apparatus consists of :—

Hardinge Mill—which is a conical grinding "cylinder" using flint pebbles as grinders, and flint lining, or steel balls and steel lining.

Classifier—which is a rectangular tank, deeper at one end than the other. At the deep end a settling pool is formed, into which the partially ground material from the mill is discharged.

The fines are washed up, while the coarse material settles and is automatically returned to the grinding mill for regrinding.

Closed Circuit signifies that the material which is insufficiently ground is separated out by the classifier and returned to the mill for regrinding. In other words, the material cannot get out of the circuit until it has been ground fine enough to be washed up at a pre-determined fineness.

Open Circuit signifies a direct passage of the material through the grinding mill without any portion being returned for regrinding.

Operating Tests.

Character of Ore under Investigation.

On the eastern end of the Mesabi Range, in Northern Minnesota, is a large formation of silicious rock which contains bands and fine grains of magnetite. The magnetite comprises about 37 per cent. of the rock, the remainder being chiefly quartzite and iron silicates. The rock has a specific gravity of 3·4, a hardness of 7, and is extremely tough.

Table 1.—Data Obtained in Open Circuit Crushing.

Table No. 1 shows results in open circuit—continuous feed and discharge without classification :—

Feed rate, variable from 3 to 18 tons per hour.

Ball load, 28,000 lbs. of 5-4-3 and 2½" balls.

Speed, 19·5 r.p.m.
Ball Mill Power, 88 kw.
Feed. Minus $\frac{1}{4}$" containing 6·72 per cent. minus 200's lawn (·063 mm.) material.
Amount of solids, about 70 per cent. by weight.

TEST NO.:

	1	2	3	4	5
Feed, tons per hour	3·66	7·40	11·00	15·00	18·00
Tons of minus 200's lawn (·063 mm.) actually produced per hour	2·24	3·77	4·85	6·03	7·67
Kilowatt-hours per ton of minus 200 mesh (·063 mm.) produced	38·55	23·53	· 18.04	14·62	11·55

TABLE 2.—DATA OBTAINED IN CLOSED CIRCUIT CRUSHING.

Feed rate, variable from 4 to 15 tons per hour.
Ball Load, 28,000 lbs. of 3" and 2" balls.
Speed, 23·8 r.p.m.
Ball Mill Power, 108 kw.
Feed, minus $\frac{1}{4}$" material.
Amount of Solids, about 60 per cent.

TEST NO.:

	108	110	111	112	113	149	150	154
Feed tons per hour	4·63	5·00	5·50	6·50	7·37	11·00	12·57	15·31
T. p. Hr. of–200's lawn (·063 mm.) actually produced	4·01	4·34	4·62	5·34	5·63	6·82	8·07	9·11
Kilowatt–hrs. per ton of 200's lawn (·063 mm.) produced	26·95	24·90	23·40	20·20	19·20	16·00	13·10	11·92

NOTE.—The duration of these tests ranged from 24 hours to several days, but in no case were data taken until working conditions were normal.

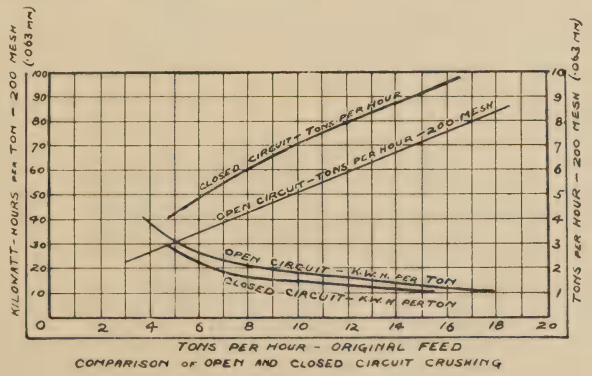

KILOWATT-HOURS PER TON - 200 MESH (·063 mm)
TONS PER HOUR - 200 MESH (·063 mm)
CLOSED CIRCUIT - TONS PER HOUR - 200 MESH
OPEN CIRCUIT - TONS PER HOUR - 200 MESH
OPEN CIRCUIT - K.W.H. PER TON
CLOSED CIRCUIT - K.W.H. PER TON
TONS PER HOUR - ORIGINAL FEED
COMPARISON OF OPEN AND CLOSED CIRCUIT CRUSHING

FIG. 2.

The following table shews the increase in tons per hour in favour of closed circuit grinding:

	At 4 tons per hour	At 7 tons per hour	At 11 tons per hour	At 15 tons per hour
Increase in tons per hour of minus 200's lawn (·063 mm.)	1·75	1·86	1·97	3·08

It must be understood that of the 150 individual tests some of the tonnages fed to the mill were greater than the effective capacity of the mill for continuous operation. In other words, the amount of circulating oversize would be too great to be ground in the same mill, or the overflow from the classifier would be too coarse; therefore, either a tonnage between the maximum and minimum amount shewn must be taken for one mill, or a secondary mill must be employed to grind some of the oversize produced by the first mill. This is known as two-stage grinding. (See Fig. 3). This shows

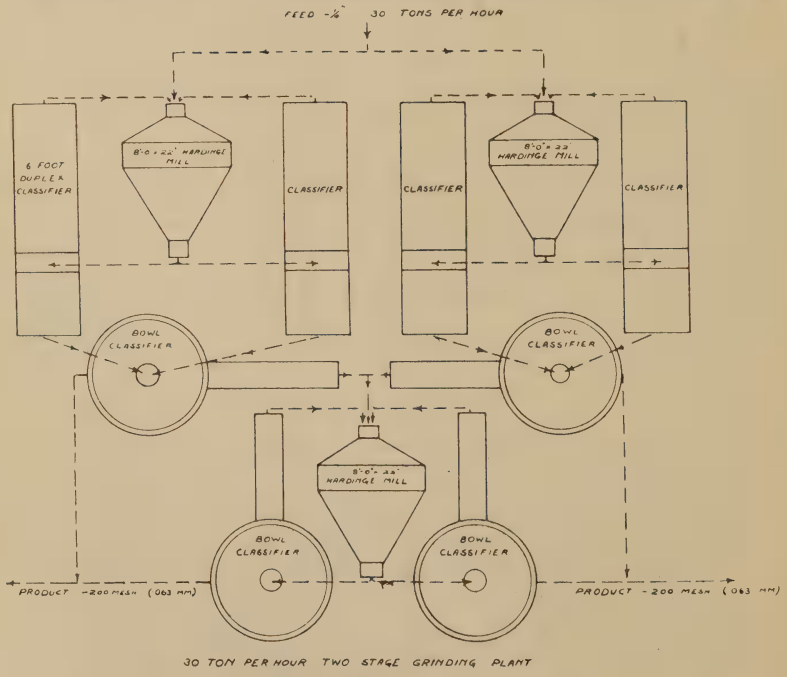


FIG. 3.

a plant that has been designed for grinding 30-tons an hour continuously, and as a result of the tests, it is calculated that at

this tonnage the 3 mills will grind their own oversize, and the classifiers will overflow a finished product at the average rate of 30-tons per hour.

Complete data is given on Test No. 113. The conditions were as follows :—

Feed rate ..	7·3 tons per hour.
Classifier ..	Dorr duplex bowl-type.
Ball Load ..	28,000 lbs. 2″ and $2\frac{3}{8}$″.
Speed	23·8 r.p.m.
Ball-mill power	108 kw.
Feed	minus $\frac{1}{4}$″ ore.
Amount of solids	About 70 per cent.

TABLE NO. 3.

Mesh (lawn)	Opening Mm.*	Ball Mill Feed per cent.	Classifier Overflow per cent.
On 4	2·2	29·18	
,, 8	1·57	27·07	
,, 14	·96	15·41	
,, 28	·45	7·93	
,, 48	·26	4·51	
,, 100	·127	3·66	1·45
,, 200	·063	2·85	11·75
,, 300	·042	1·61	14·95
Thru. 300	·042	7·78	71·85
		100·00	100·00

The Clasifier was set to overflow approximately material passing 100's lawn.

Another feature affecting grinding efficiency is the size of balls used for a given range of reduction.

DATA OBTAINED IN CLOSED CIRCUIT CRUSHING WITH LARGE AND SMALL BALLS.

Test No.	Tons per hour	Ball Sizes	Tons of minus 200's lawn	Kilowatt hours per ton
149	10·8	5″, 4″, 3″ & $2\frac{1}{2}$″	6·3	17·15
12	11	3″ & $2\frac{1}{2}$″	6·82	15·8

It must be observed, however, that the feed in both cases was $\frac{1}{4}$″ and less. Had the feed to the Hardinge Mill contained 1″ material, then some large balls would have been necessary to effect the efficient reduction of the 1″ pieces.

* It has been assumed that openings in screens correspond to I.M.M. Standard.

Relation between Speed of Mill and Size of Balls.

Table 8.—Classifier Sands (Oversize returned for regrinding) From Balls of 4", 3", 2½" & 2" in diameter.

Mesh (lawn)	Opening Mm.	19·8 r.p.m. %		21·1 r.p.m. %		23·8 r.p.m. %	
On 4	2·2	1·84		1·46			
,, 8	1·57	1·32	9·38%	0·82	6·70%	0·66	
,, 14	·96	1·86		1·14		1·34	6·19%
,, 28	·45	4·26		3·28		4·19	
,, 48	·26	9·20		8·82		9·65	
,, 100	·127	25·84		26·06		29·44	
,, 200	·063	34·86		35·64		36·22	
,, 300	·042	11.88		11·46		10·98	
Thru. 300	–·042	8·94		11·32		7·52	
		100·00		100·00		100·00	

It will be noted that the higher the speed (within limits) that there is less of the coarser material in the classifier sands.

Relation Between Classifier Sands (Oversize) From Different Sizes of Balls when all other Conditions are Equal.

Table No. 10.

Mesh (lawn)	Opening Mm.	Average Size 2¼" %	Average Size 2⅝" %
On 4	2·2	10·26	0·80
,, 8	1·57	9·64	3·22
,, 14	·96	9·86	7·44
,, 28	·45	14·38	18·84
,, 48	·26	18·10	31·04
,, 100	·127	19·78	25·36
,, 200	·063	10·08	7·92
,, 300	·042	2·36	1·94
Thru. 300	·042	5·54	3·44
		100·00	100·00

From the series of tests, the following conclusions may be drawn :—(*a*) If the balls or pebbles are large, and speed of mill is high, crowding will appear at the finer sizes in classifier sands (*i.e.* oversize).

(*b*) If the balls are small or the speed is low crowding will appear at the coarser sizes in the classifier sands (*i.e.* oversize).

(*c*) The product from a mill with large balls and high speed will be more uniform than the product from a mill with low speed and small balls.

From the results of the 150 tests carried out on a commercial scale, the following plant was designed, having a capacity of 30-tons per hour, for the production of the following grading analysis residue :—

On 200's lawn	·063	..	..	7·15%
,, 300's lawn	·042	..	..	13·75%
Through 300's lawn	—·042	..	..	79·10%

This Plant of 30-tons an hour represents only one unit of the plant to be subsequently erected. The ultimate capacity will be 40,000 tons per day. This example has been selected on account of its magnitude and the thoroughness with which all tests were carried out, and as representing the most up-to-date and efficient method of fine grinding. Let it be remembered that the ore had a hardness of 7, and was extremely tough so that it offered the maximum resistance to reduction. The Hardinge Mill used was 8′ in diameter and the cylindrical portion was only 22″ long. Now we have been dealing with an ore, the average specific gravity of which is 3·4. The ore is a mixture of quartzite and magnetite—about 35% of the latter. The Sp. Gr. of magnetite is about 5, and that of quartzite about 2·6, and yet, despite the difference in specific gravity, the final product is similar to the initial feed with regard to its component parts, because of the continuously circulating load. We will now take another example on a smaller scale, in which the material treated was barytes.

The product desired was a maximum amount through 300's lawn (·042 mm.). In this case no iron contamination is possible as the barytes is used as a paint filler. Owing to the high specific gravity, large pieces of barytes were used to do the grinding ; the discharge from the mill went to a mechanical classifier ; the overflow from the classifier was further classified in order to obtain all minus 300's lawn (·042 mm.) and the material coarser than 300's lawn (·042 mm.) was returned for regrinding. An 8′ dia. × 30″ cyl. Hardinge pebble mill was used, consuming 50 horse-power. The output was $1\frac{3}{4}$-tons per hour of finished product. At this plant 2–5′×22′ tube mills had previously been employed as batch grinders, absorbing about 160 horse-power, with a joint capacity of 2 tons an hour, until the above continuous system was installed.

Another example is the grinding of silica at Still River, Connecticut. The plant originally contained Arrastras, *i.e.*, large stones which are dragged round in a pit ; twelve of these mills consumed over 100 horse-power, and gave a total tonnage of 1 ton per hour from 1″ to 90% minus 300's lawn (·042 mm.). An 8′ dia.×36″ cyl. Hardinge pebble mill was installed, using flint pebbles, consuming 45 horse-power, in closed circuit with a classifier. The results of the screen analysis of feed and product are shown :—

TEST NO. 1.

Mesh (Lawn)	M.M.	Feed Per cent. all thru. 1″	Discharge % Classifier Overflow
4	2·2	48·0	
8	1·57	19·0	
14	·96	10·1	
28	·45	6·0	
48	·26	3·3	
100	·127	2·6	
200	·063	2·5	0·0
On 300	·042	3·5	23·0
Thru. 300	–·042	5·0	77·0

Capacity in tons per hour 2·4.

TEST NO. 2.

Mesh (Lawn)	M.M.	Feed Per cent. all thru. 1″	Discharge % Classifier Overflow
4	2·2	48·0	
8	1·57	19·0	
14	·96	10·1	
28	·45	6·0	
48	·26	3·3	
100	·127	2·6	
200	·063	2·5	0·0
On 300	·042	3·5	3·2
Thru. 300	–·042	5·0	96·8

Capacity in tons per hour 1·7.

The following is a summary of the foregoing figures in terms of horsepower hours absorbed per ton of finished product :—

Iron Ore :—		
Closed Circuit Grinding.	7·37 t.p.hour feed to mill	= 25·5 H.P.-hours per ton to –·063 mm.
Open Circuit Grinding.	7·4 t.p.hour feed to mill	= 31·6 H.P.-hours per ton to –·063 mm.
Barytes :—		
Closed Circuit Grinding.	1¾ t.p.hour feed to mill	= 29 H.P.-hours per ton to –·042 mm.
Batch Grinding.	2 t.p.hour feed to mill	= 80 H.P.-hours per ton to –·042 mm.
**Silica* :—		
Closed Circuit Grinding.	1·7 t.p.hour feed to mill	= 28·8 H.P.-hours per ton to –·042 mm.
Batch Grinding.	1 t.p.hour feed to mill	= 100 H.P.-hours per ton to –·042 mm.

* Calcined and water quenched.

The Hardinge Mill.

A general view of the Hardinge Mill is shewn on Figs. 4 and 5.

It is not intended in this paper to show more than the principle suggested for grinding to the Pottery Trade requirements. The sizes of the apparatus needed for the grinding and classifying of the materials that make up the finished slip can only be determined when the actual requirements, both in capacity and fineness, are known for any given problem.

The importance of grading the finished product correctly is realised as A.B.C. & D. products will probably bear different relations to each other for particular requirements. This grading can be regulated by :—

1. Varying the initial feed to the mill.
2. Varying the speed of the grinding mill.
3. Varying the amount of dilution when grinding.
4. Varying the size of grinding media.

The figures given from actual practice support the contention that any degree of fineness can be obtained by closed circuit continuous grinding, and at a considerable reduction in power and labour costs over open circuit or batch grinding methods.

A short description follows of the machinery employed in practice from which the above data has been taken.

It will be noted that the cylindrical portion of the mill is quite short, although the foregoing figures have shown that a maximum amount of fine material has been produced per horse-power.

Action of the Hardinge Mill.

Owing to the conical shape, a positive classification of the grinding media takes place, due to the different speeds at which different parts of the mill revolve. The large balls or pebbles remain in the cylindrical portion of the mill, while the smaller balls or pebbles take up positions nearer the discharge end, consequently we have large pebbles acting on the incoming coarse feed, and, as this material becomes broken up under the impactive action of the large balls or pebbles, it travels towards the discharge end where it meets the small balls or pebbles, which grind by attrition, and thus we have, in one mill, an energy output in proportion to the work to be done—this peculiar action can be noted in the glass model before you. The particles undergoing the grinding action are also influenced by the shape of the mill in that their discharge is automatically hastened by the reducing diameter of the discharge cone. Thus, the finest material is automatically removed from the grinding zones soon after it is formed. The grading of this product is governed by several operating factors referred to previously. In batch grinding, after say grinding for one hour, a certain amount of finished material is produced, and yet this

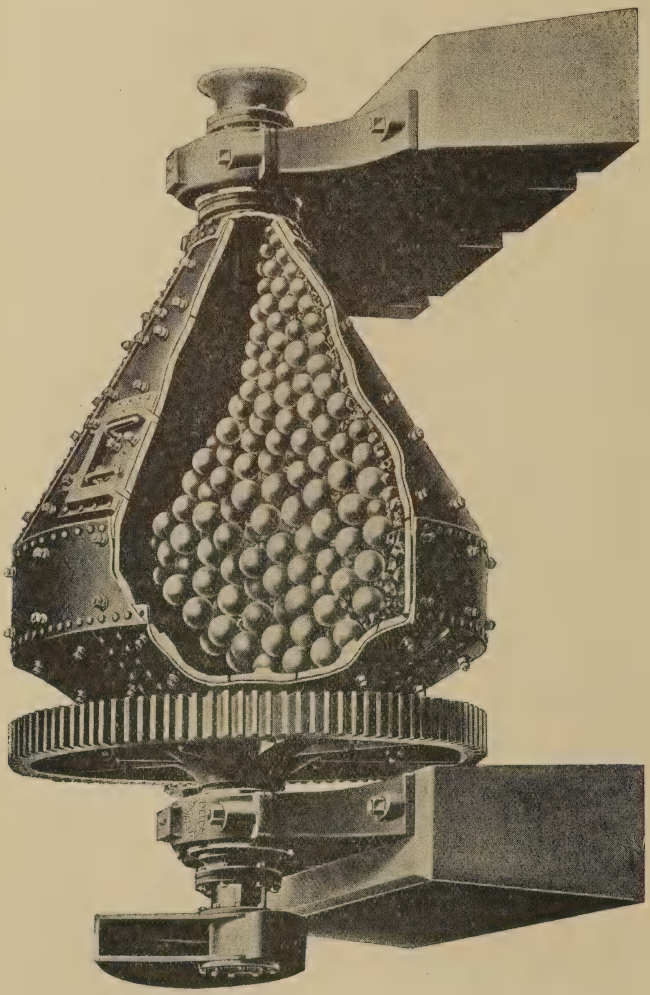


FIG. 4.

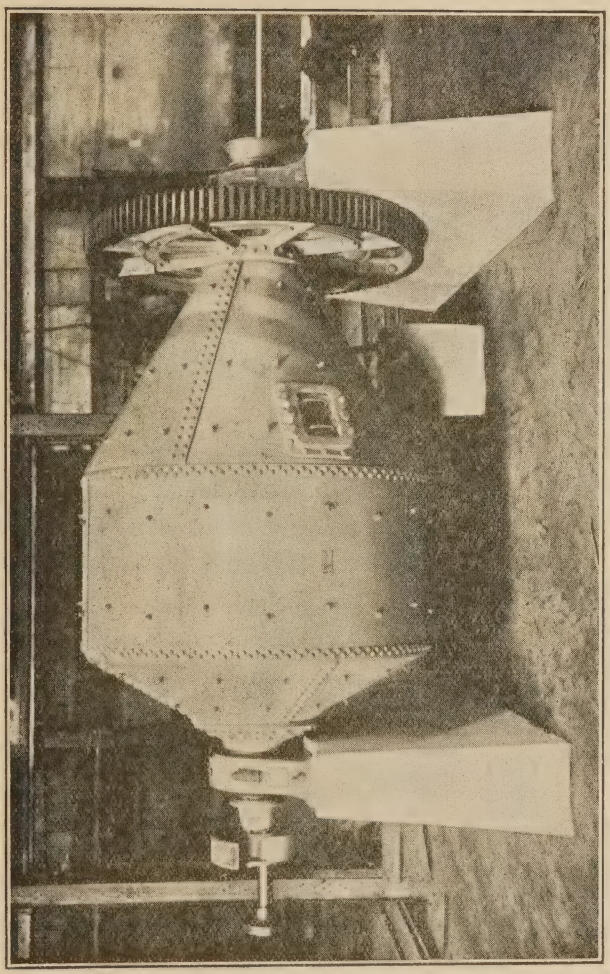


FIG. 5.

material must remain in the mill until every particle is reduced to a sufficient fineness. Not only is energy wasted in reducing material already fine enough, *but the finished material retards the grinding of the unfinished material*, and it is this fact which opens up an avenue for increasing grinding efficiency by the closed circuit system.

The Classifier.

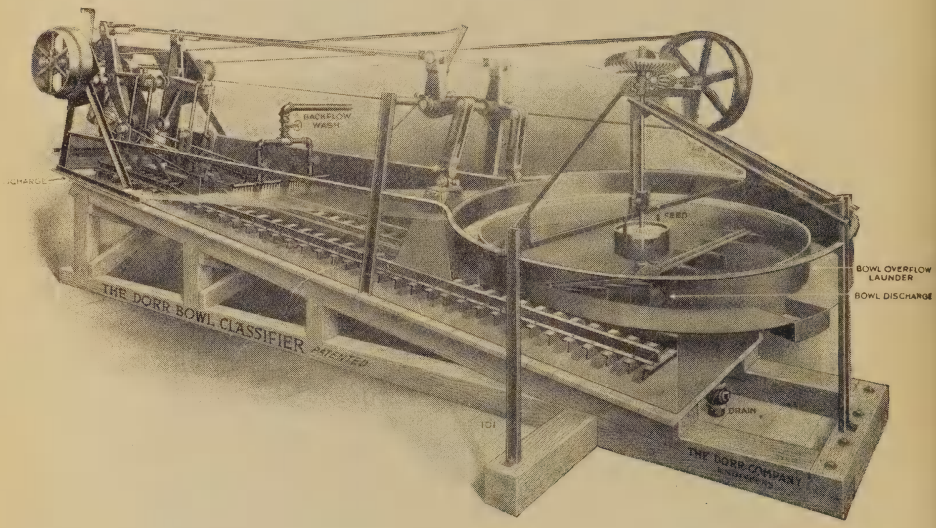


Fig. 6.

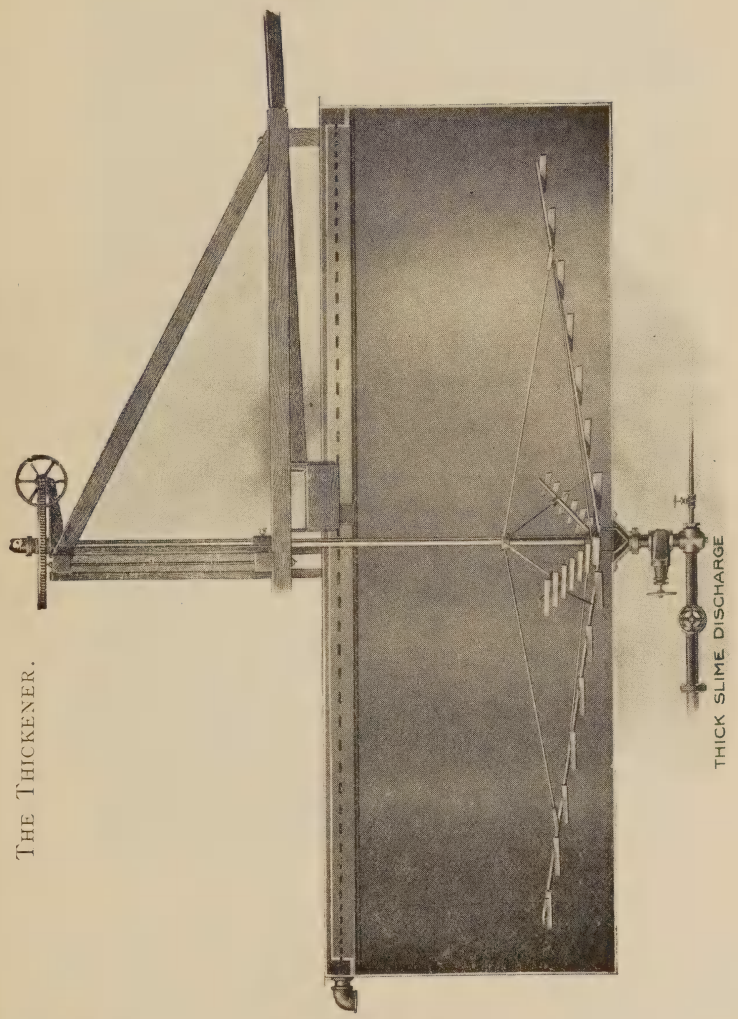
The Classifier is a rectangular tank deeper at one end than the other; this tank is mounted on wooden supports and is set at a slope varying between 1″ and 4″ per foot, in a downward direction towards the overflow end. The shape of the tank causes a settling pool to be formed at the overflow end, and the pulp from the grinding mill is discharged into this settling pool. The rakes, which are mechanically operated, create an agitation in the settling pool which causes the overflow of the fines, while the sands which settle at the bottom are raked out of the classifier and returned to the mill for re-grinding.

The grading of the overflow depends upon the following:—

1. Dilution of pulp.
2. The speed at which the rakes move.
3. Slope of classifier.

To obtain Fine Overflow—Decrease rake speed.
,, ,, ,, ,, —Increase water to classifier.
,, ,, ,, ,, —Decrease slope of classifier.

To obtain coarser products, the above conditions would be reversed.



THE THICKENER.

FIG. 7.

The function of this apparatus is to separate the excess water and to discharge continuously a thick pulp.

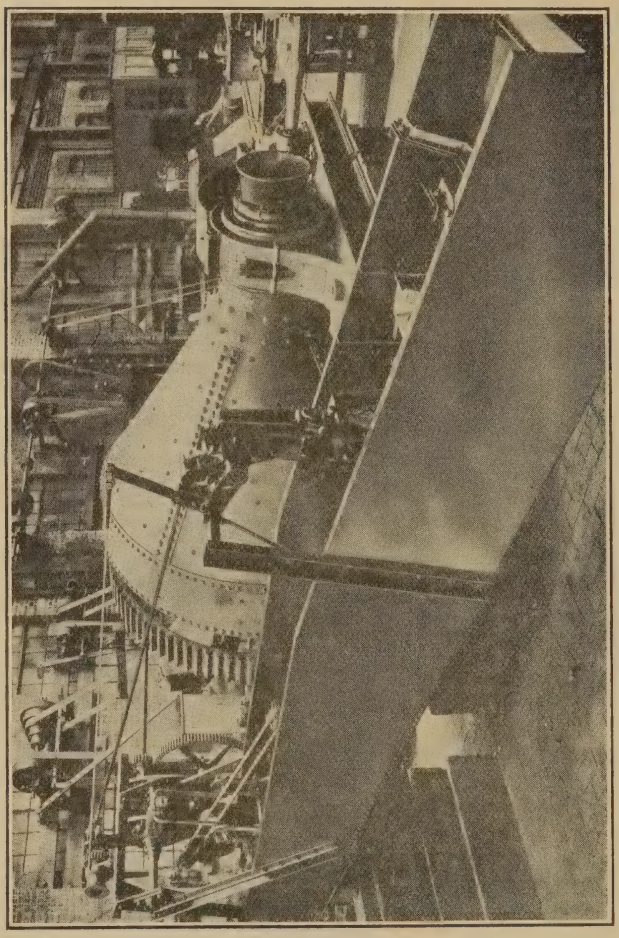


FIG. 8.

This illustration shows a Hardinge Mill and a Dorr Classifier set up at the Works before shipment. In the foregoing examples, the finished products ground at the various plants were determined more by the size of the largest particles than the amount of "slime" or "flour" that was produced. In grinding to the Potters' requirements, I am informed, however, that this method of determining the critical grinding point will not hold good because it is necessary to produce a more or less fixed proportion of "slime" or exceedingly fine material, in addition to grinding through a given lawn. In order to meet the grinding requirements of the Pottery Trade,

it will be necessary to feed the grinding mill at such a rate that a maximum amount of the desired product is obtained per horse-power—in other words, the passage of material through the grinding mill must be long enough for efficient reduction but not long enough to create the cushioning effect caused by an accumulation of very fine material. It now remains to determine the size of the grinding unit in either one or two stage grinding for any given tonnage, and as before mentioned, this can only be determined when all the factors are known concerning any given problem. Fig. 9 shews an illustration or a flow sheet of a typical fine grinding closed circuit unit, which it is contended would be applicable to the Pottery Trade requirements.

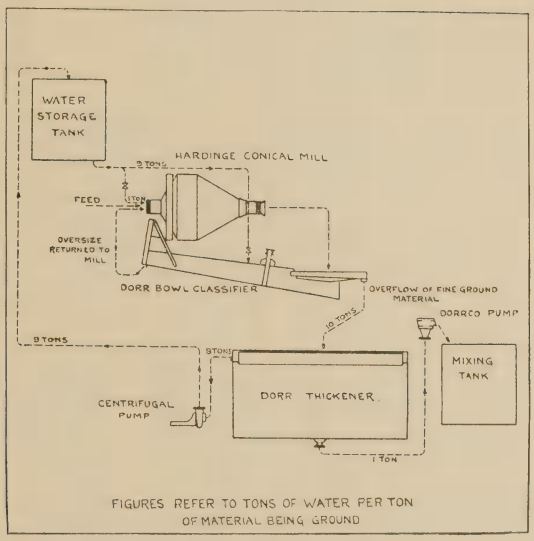


FIG. 9. (FLOW SHEET OF PLANT).

The ratio of water to flint or stone is shewn in tons per hour.

DISCUSSION.

MR. CUTHBERT BAILEY:—We have all listened to Mr. Farrant with very great pleasure and interest. You will all agree, I am sure, that he is tackling a subject that is of supreme importance to the potting industry, and a subject which, if it can be tackled satisfactorily, will make life worth living—probably for the first time—for a good many of us in this room. It is a big problem, and there will no doubt be a good many questions that we shall be very anxious to put to Mr. Farrant. Personally, I may say that I am not quite

satisfied yet on several points. But one thing I do like about Mr. Farrant, if he will allow me to put it personally. Not only has the subject matter of the lecture been interesting, but the outlook of the lecturer has impressed me greatly. He comes here with a lecture that is primarily given with the object of promoting discussion and eliciting information. Mr. Farrant probably knows human nature and the world sufficiently well to agree with me when I say that the great bulk of the lecturers come here with the idea of telling us what we ought to do, and if we do not thoroughly agree with them, they are apt to class us as a set of blockheads. In probably nine cases out of the ten, we do prove a pack of blockheads, but in the tenth, we may happen to know something. Now we do happen to know something on this particular subject, because it is one which is of very vital importance to us,—the one difficulty that we have experienced in the past in connection with our materials has been—to use Mr. Farrant's own words—to get them "classified down to a specified grain."

The vote of thanks to a lecturer, as I understand it, generally comes at the end of the discussion, in which case the proposer and seconder have had the time and opportunity to round off their arguments. In view of the fact that the discussion has yet to come, I will merely finish by saying how extremely interested I, personally, have been in the subject matter of the lecture, and it gives me very great pleasure to propose a hearty vote of thanks to Mr. Farrant for having come before us to-night with such an interesting discourse.

Mr. W. Lindley:—I, too, have listened to Mr. Farrant's lecture with very great pleasure, and I may say that some of us potters might not have been so white-haired to-day, had it not been for this very great problem that we have now before us for discussion. I am glad to notice that the lecturer appreciates the fact that we want a peculiar type of grinding in the pottery trade. It is a fact that we do, and it is because of that fact that some of us old-fashioned people do not take quite so readily to cylinder grinding.

A point that Mr. Farrant deems sufficiently important to present to us in italics is that *an enormous amount of time is wasted in grinding material already fine enough*. Now some of us old-fashioned potters seem to think that finer and yet finer grinding makes it still better for us, for it stops that insidious thing that we so much dread, viz:—crazing. Therefore, if we get our materials a little finer ground we never grumble: on the other hand we appreciate it.

Mr. Farrant's slides are excellent. I could not help thinking that a great amount of ingenuity has been spent in order to gather together such a concentration of grinding plant under one roof as that which he illustrated in connection with the copper plant in the United States. This struck me as being quite a grand installation.

I have much pleasure in seconding the vote of thanks to Mr. Farrant for his paper.

Mr. Farrant:—I thank you very much for your reception. I just want to reply to the point raised by Mr. Lindley, and that is, that from the point of view of the potter, nothing can be ground too finely; in fact, you do not mind your material being ground a little extra. A point I want to make clear—and I think it is a reasonable point—is this; supposing you have a material that has to be ground for 20 hours, which is often the case; it stands to reason that after grinding for one or two hours only, there must be at least some proportion of the charge that is already fine enough. Now supposing you stop the cylinder in an hour and make an elutriation test. There will surely be some slight percentage of the material that would already be finer than ·01 of a millimetre, and therefore meeting your requirements of fineness. It may only be 5 per cent., but my point is, that if, after this has been formed, you can take it out and get rid of it, you will have a better chance of getting hold of the other particles which would otherwise be cushioned by this fine material, further grinding being retarded thereby. That is the whole object of closed circuit grinding. I would like to make it quite clear that by adopting closed circuit grinding you are not in any way putting any limits upon fineness.

Mr. Lindley:—I may say that potters dread uniformity of grinding.

Mr. Farrant:—With regard to uniformity: Here is a sample of ground limestone. I admit it is not so hard to grind as silica, it has a higher grindability. But this was elutriated at your School of Technology to-day. Although this particular test may not compare favourably with the grinding of flints, it does serve the purpose of a comparison. I do not think anyone could claim that it exhibits uniformity of grinding in the sense that the particles are all of the same size. You get variation in the sizes of particles with closed circuit grinding as by any other system of grinding. Here is a sample of ground felspar. I do not know for what purpose it was used, but Dr. Mellor very kindly elutriated this for me, and here is the result. It was only ground to pass a 100's lawn, but an elutriation test shews 7·76% left on the equivalent of a 200's lawn, 57·2 per cent. + ·01 mm. and 35 per cent. -01 mm. It is not contended for a moment that that would be ground satisfactorily for the use of potters, but it does shew, I think, a very close relation between the component parts of the ground material by this process and that of ordinary grinding. The capacity of that particular mill was two tons per hour. The horsepower was 50. Now I contend that if that capacity had been reduced to one tenth an hour we should have eliminated the whole of that material that was coarser than a 200's lawn. Therefore it is mainly a question of the

rate and size of the initial feed which determines the fineness. The minor adjustments are the speed at which the mill is rotated, the sizes of the grinding media and the amount of water used.

I have a number of examples of ground materials with me, but unfortunately, I have not the latest particulars in regard to flint, and I recognise that this is the material which would best illustrate my points in connection with the pottery trade. Some work has been done on flint, and I cabled over to America for the results. If I could have shown you to-night the results of an elutriation test on flint, I am confident it would have been quite sufficient to satisfy you that we are on the right track.

I think it is only right to mention that a great many people have got the idea that these mills are all "made in America." I may say that these mills for the past ten years have been manufactured in England.

Mr. Bailey:—If Mr. Farrant had been able to give us the information that he cabled for about flint, I think there would have been practically no criticisms. I fear, however, that I am still unconvinced in regard to some of Mr. Farrant's very conservative statements. The argument that after, say, a quarter of an hour's or half an hour's grinding quite a considerable proportion of the material is down to 0·01 of a millimetre is, I believe, a perfectly true argument in connection with what Mr. Farrant calls batch grinding—what we call pan grinding—because if particles once get under a runner weighing 20–25 hundredweights, they have had all they can stand. When it comes to cylinder grinding, however, it is not one huge crushing effect, but a tap, tap, tap which gradually breaks the particle down, but does not bring it down speedily to an impalpable fineness. I very much question whether a cylinder mill grinding continually with a slow, gradual feed is going to give the potter his 50 per cent. of fine fraction. Another point I would like to query is in connection with the classifier. What Mr. Farrant calls "rakes" I can quite understand would satisfactorily rake up coarse particles, but will they rake up particles that are already down to 0·04 mm., or a 300's lawn? Then again, when the rake is raking up the particles, is it not distributing the material, with the natural result that a certain amount of the coarse particles are plunged up and passed over with the overflow?

Mr. Farrant:—The points raised are very well taken. When I referred to batch grinding, it was not necessarily pan grinding. Anything is batch grinding that is not continuous. If you fill a cylinder full of material, grind it, and empty it, we describe that as batch grinding. It is just as much batch grinding as pan grinding.

In the case of the ground limestone elutriation test we had 44 per cent. finer than 0·01 mm.

Mr. Bailey:—But that is a softer material. You drew our attention to that point.

Mr. Farrant:—Yes, but the relative hardness of materials affects the capacity to a greater degree than the fineness. For example, if we wanted to reduce two different materials—say silica and limestone—to the equivalent of a 300's lawn we should find that the percentage of products passing 300's lawn would be approximately the same, but we should get less capacity with silica than we should with limestone.

With regard to the classifier, I am inclined to agree with Mr. Cuthbert Bailey. It is only quite recently that this question as to the slipping back of the fine particles as soon as the rakes are lifted has come up from a practical standpoint. There is a tendency —especially in regard to the material ground to the fineness of a 300's lawn—for the fine particles to slip backwards, and a suggestion was put forward in order to overcome the difficulty. We adopted the principle of the hydro settler, but varied the mechanism, which consists of a tank with a slowly revolving stirrer. The coarse solids which settle out are drawn to the centre, and returned to the mill by a pump. The overflow, which is on exactly the same system as elutriation, is regulated to carry over those particles which are desired. It has the disadvantage of requiring a pump to deliver the coarse material back into the grinding unit, but it operates on a finer pulp, than can a classifier. The classifier is limited not so much by the fineness of the overflow as its inability to rake up materials at the fineness less than 300's lawn. I think this is a point in regard to which we shall still have to do a little more experimenting. As a matter of fact, we are shipping out to Belgium, next week, a small unit on that basis.

With regard to the question as to the disturbing element of the rake, I think I can answer that by saying that the disturbance is proportional to the rake speed. The speed can be so adjusted that no particles above the fineness of a 200's lawn can be overflowed.

Mr. W. E. Goodwin :—If the lecturer would like some information, I think I can supply him with it. And I think I am the only man in the room that will. The degree of fineness more largely depends upon whether the manufacturer is busy or not. If he happens to be busy, then the degree of fineness does not interest him so much. It is easy enough to prove that statement. You never heard of a miller receiving a complaint of rough ground flint or stone during the war.

The Chairman :—I think we shall have to contradict that, Mr. Goodwin.

Mr. Goodwin :—I have had my ears and eyes open, and I repeat that during the war there was not a complaint of rough ground material. But now we are beginning to receive them. Now the average potter does not understand whether his material is sufficiently ground or not. He knows whether it is too rough for

him to use it, but he does not know whether it is too fine. The miller tests the degree of fineness with his lawn, and if the lawn rejects anything, then he knows that it is too coarse. But he does not know how fine it is, nor does the average potter. I do not see how they can tell at present whether it is too fine or not. Of course, if it were too fine, it would not settle, and the miller to-day is having the greatest difficulty with settling at his mill. It is really ground a great deal finer than it was in my day. At one time the manufacturer was quite satisfied if the material went through a 120's lawn. And there are men around me who will back me up in that statement.

Mr. Bailey :—Yes, and they are white-haired to-day.

Mr. Goodwin :—To-day the potters want the material ground distinctly finer. There may be advantages in that, but I do know that at one time the bulk of the millers' ground material went through a 120's lawn, and both they and the potters were satisfied with it. Nowadays the potters want it to go through 130 and 140's lawns, and the finer you grind it the more difficulty you have with it settling, and incidentally up goes the cost. I still adhere to my statement that the average potter is not concerned so much with the degree of fineness as he is with the degree of coarseness, and that if he is busy he is not very particular as to whether the material is coarse or not, within reasonable limits.

The Chairman:—I fear I still fail to grasp Mr. Goodwin's point.

Mr. Bailey :—I think that every potter in the room well knows whether his milled material is or is not fine enough, and I think Mr. Goodwin is, as he says, the only man in the room who would make the statement that he does not. With all due deference to Mr. Goodwin, who is an expert miller, he evidently does not know the potter's difficulties, and I would beg the lecturer not to be influenced by what Mr. Goodwin has said. Every potter in this room who knows his business makes it his duty to know what fine fraction he is getting in his milled material—not merely occasionally, but every day in the week. Moreover, there is no potter in this room, who knows his business, who does not also know that a lawn is no test at all of fineness, but simply of coarseness.

Mr. Farrant :—I can quite realise that in the pottery trade the method of testing the degree of fineness may be altogether different from those which obtain in other industries. Outside the Potteries we have only been expected to judge the fineness by the size of the largest particles in any given product.

Note by Mr. Farrant:—Since the discussion, additional data have been obtained which indicate that the Bowl Classifier would best meet the requirements of the Pottery Trade; it combines the increas-

ed settling area of the hydro settler and the mechanical advantage of the raking mechanism of the standard shaped classifier; the construction of the bowl is such that the slight agitation caused by the rakes is greatly diminished. Further, when the sands or oversize returned for regrinding contain material coarser than 200's lawn, the slipping action referred to in the discussion is overcome.

Mr. F. Wooldridge:—Can the lecturer give us any scale, which depends upon the speed of output of the continuous mill for fineness—either in the size of the lawn or the millimetre particle? That is to say, supposing we are taking a mill grinding five tons per hour, or any other quantity you like, and we reduce the capacity to 4, 3 or 2 tons per hour, can he give us the relative ratio of the size of the particles the output will go up to?

Mr. Farrant:—No, sir, I cannot; and I do not know any grinding man who could tell you that definitely on any given substance. He could only do it by carrying out tests. I think I can tell you approximately. I assume you are speaking of the size of the discharge from a given feed. By wet grinding with the closed circuit system on an eight foot mill we are grinding at the rate of 5 tons an hour to somewhere in the neighbourhood of a 30's lawn. 4 tons an hour we are grinding to a 40's or 50's lawn; 3 tons an hour to 60-80's lawn; and 2 tons an hour to about 100's lawn. So that you may reckon that for the lower capacities at one ton per hour the fineness would be about 150's lawn, and $\frac{1}{2}$ ton an hour somewhere in the region of a 200's lawn.

Mr. F. Wooldridge:—Can you bring it down to a 400's?

Mr. Farrant:—Yes, but at a considerable sacrifice of capacity. I am speaking now of an uncalcined flint. For a calcined flint the capacities would be increased. I would expect that at least $\frac{1}{2}$ ton an hour an eight feet mill would grind to the potters' requirements.

Mr. A. Fielding:—Suppose the calcined flint were taken straight from the calcining kiln and not reduced down before being fed to the cylinder, what difference do you think that would make in the output? Or do you think it would be better first of all to put it through a stone crusher, crushing to about $1\frac{1}{2}$" in size? Is it a commercial proposition to feed the material to the mill about $1\frac{1}{2}$" in size?

Mr. Farrant:—From a sample that I saw in one of your grinding mills here, I would say that the percentage that would remain on a $1\frac{1}{2}$" screen would be about 10 or 15 per cent. Would that be in line with your materials?

Mr. Fielding:—It would be much more than that—a lot more.

MR. FARRANT:—Well, that would have a distinct effect upon the capacity, because to break it down in the mill to 1½" or an inch does take a good deal of time, whereas if the flint were small to begin with, it would probably fracture at one blow of a pebble. You can feed a ball mill with 3" material, but its efficiency does not begin to reveal itself seriously until it is fed with material of somewhere about an inch in size. The feed should be such that the biggest of the pieces can be cracked in one blow. Unless that can be done, the large pieces roll round with the Grinding media and the edges are simply worn off the largest pieces because they are too large to be fractured by one blow. So that if it is possible first to crush your flint you would get greater efficiency. The question of a coarse or a fine feed is most important. The finer (within limits), you can get the feed into the grinding cylinder the better it is, without question.

MR. F. WOOLDRIDGE:—Is that a fact that has been determined by experiment? Supposing you took a Griffin mill. Do you contend that material put through a Griffin mill to pass a 60's mesh would go through a mill more efficiently than material broken down by a crusher to ¼" mesh?

MR. FARRANT:—In the case cited, I consider the overall efficiency would be greater if the pebble mill were to take the ¼" feed direct. I do not know of any jaw crusher in use on a commercial scale which would give you a ¼" product from 6" pieces. I am not suggesting that in initial crushing you should break the material down to too fine a feed. My suggestion is that the single crusher might be advantageously closed up to give a finer product to the cylinders than is the case at present. You can, of course, carry that principle too far. To pass the material through a series of two or three crushers would, I think, be going too far.

MR. F. WOOLDRIDGE:—Can you give me the amount of moisture that you said was the least that you got in from the thickener?

MR. FARRANT:—48 per cent. by weight.

MR. FIELDING:—It is all a question of commercial costs, as to whether it is cheaper to use a cylinder as a crusher to a certain extent or put down a separate machine.

MR. FARRANT:—A continuous cylinder will take anything that the ordinary cylinder will grind. My contention simply is that if you can, with the same machine, reduce the size so that the majority of the coarse work is done by the crusher, you can grind it more efficiently.

MR. FIELDING:—I quite agree. But which is the cheaper?

MR. FARRANT:—I think there is no doubt that the crusher would be the cheaper proposition.

MR. FIELDING:—Up to a point. But after that point the cylinder will be the cheaper. The question is, at which point does the economy begin to reveal itself?

MR. FARRANT:—There is no doubt that crushing as a department is much cheaper than grinding. Therefore, use the crushing department as much as you can. It is not until the crushing plant begins to grind rather than to crush, that its effectiveness begins to be realised. Speaking generally, one might say that crushing is the process of bringing the material down to about 1" in size. Grinding begins from 1" downwards. If you are crushing coarser than an inch you are letting the crushing plant off easily, and merely piling the agony on the grinder. It is rather a big question. It depends largely on the tonnages that you are handling. For a big capacity, I would recommend crushing to $\frac{3}{4}$" by means of crushers. But for smaller plants I would recommend crushing to an inch as being the more economical.

MR. FIELDING:—Most of the potters' products are wanted at the rate of about 150 to 200 tons a week. If you take a ton and a half per hour, 24 hours grinding would yield 36 tons per day.

MR. FARRANT:—I quite appreciate that. My object in giving you in my paper the larger figures was to show the thoroughness with which this system has been tested. These firms handling products in such huge quantities would consider this expense unless there were some very strong reasons for spending the money on them. They have proved conclusively that in a large number of cases in particular fields, closed circuit grinding is really beneficial and money is saved. As to whether the same thing can be done in the pottery trade can only be determined by investigation and discussion, and it is because of this that I am here to obtain your views. It will then be up to us to put forward a definite scheme for your consideration.

MR. A. FIELDING:—Which is the nearest place to Stoke-on-Trent where one of these machines is fixed?

MR. FARRANT:—There is one in Wales grinding raw, dry, uncalcined silica. It was not my business to find out where this material was going to, but I should not be at all surprised if it were finding its way to the Potteries. In that case it might be rather difficult for a pottery manufacturer to see the machine in use.

DR. MELLOR:—I think that material is used for soap-making, and also, to a certain extent, in the making of rubber.

MR. FIELDING:—What would be the cost of a complete installation?

MR. FARRANT:—An eight-foot mill complete with silica lining would be roughly about £900. Its weight is about $7\frac{1}{2}$ tons. Its speed would depend on the size of the feed.

MR. C. D. GRIMWADE:—It seems to me that in a mill of this type the pebbles would fast become uniform, since the heavier work is continually thrown on the largest pebbles, whilst the smallest pebbles near the exit will take a long time to wear out. Can the lecturer say if that is so, and are there any preventive measures against this?

MR. FARRANT:—I have had a good deal of experience with pebble mills, and I have been inside a large number, but I have never seen uniform pebbles, for the reason that fresh pebbles are fed in every day. It depends on the size of the feed whether we put in 3″, 4″ or even 5″ pebbles. Ordinarily 4″ pebbles are fed in every day to keep pace with the consumption. Roughly speaking, pebbles wear down in proportion to their diameters and as fresh pebbles are fed in each size gradually diminishes. I have seen pebbles no larger than the top of a pencil—when they have been so small that it has been perfectly useless to keep them in use any longer.

MR. W. PODMORE:—Do you claim greater efficiency with your mill than with a continuous tube mill?

MR. FARRANT:—Yes, sir. For the reason that in dealing with any degree of fine grinding with a long cylindrical mill you have produced a certain amount of material already fine enough at a distance of about 18″ from the feed end. This material has then to travel right through the mill before it is discharged. During its travel it is preventing other material from being ground. That is primarily the reason of the economy by the closed circuit system of grinding.

MR. PODMORE:—It seems to me that your mill grinds only in one place, that is to say, on the outside periphery. As it gets towards the outlet the grinding is decreasing. In a continuous tube mill with the same periphery speed, would not that tend to give a greater output per horsepower?

MR. FARRANT:—No, sir; it certainly would not.

MR. PODMORE:—In your cylinder you are merely tumbling the stuff about without grinding, because the speed is too low.

MR. FARRANT:—To reduce large particles you require cascading action induced by a relatively high speed, while for reducing small particles additional grinding is required induced by a lesser peripheral speed. In a long cylindrical mill you have a mixture

of pebbles. The large pebbles are grinding particles which are practically finished. There is no classification of the grinding media in a tube mill, whereas in the Hardinge Mill there is.

MR. PODMORE:—Have you proved in actual practice that the economy in horsepower is greater by your system than by a continuous tube mill?

MR. FARRANT:—Yes. In one case a continuous tube mill was operated for a period of 12 months alongside one of our machines grinding to the same mesh, and it was found that we got a greater tonnage per horsepower. A view of one of the large installations of Hardinge Mills was shewn on the screen—this plant was erected after a competitive test between a Hardinge Mill, or tube mill, and a grinding pan.

MR. PODMORE:—Have you any figures relating to tons of material produced per horsepower?

MR. FARRANT:—I have already given figures shewing that 80 horsepower was used with batch grinders, whilst only 45 was used by closed circuit grinding.

MR. PODMORE:—I am not referring to batch grinding, but to continuous grinding. I am merely setting a continuous tube mill against yours.

MR. FARRANT:—I do not think I could have shown a better example than the 64 Hardinge Mills installed after a competitive test. Figures of such a test are given below:—

8-ft. × 36-in. HARDINGE PEBBLE MILL

vs.

6-ft. × 9-ft. CYLINDRICAL TUBE MILL.

January, 1915.

	Hardinge Mill.	*Tube Mill.*
Per cent. solids	44·4%	44·1%
Tons per 24 hours	217·1	145·0
Horse power	59·41	50·0
,, ,, per ton	6·947	8·299
Tons per horse power	3·66	2·9
Relative efficiency	100%	79·3%
Pounds pebbles per ton	1·151	0·862
Cost of pebbles ,, ,, @ 1·349 cents per lb.	1·55 cents	1·16 cents
,, ,, lining ,, ,, ...	·62 ,,	1·05 ,,
,, ,, power ,, ,, @ 1.106 cents per KWH.)	5·73 ,,	6·85 ,,
,, per ton for power, pebbles, and lining ..	7.90 ,,	9·06 ,,

SCREEN ANALYSES.

	Hardinge Mill.		*Tube Mill.*	
	Feed	*Product*	*Feed*	*Product*
On $\frac{1}{8}$″ mesh ..	0·5	0·0	0·9	0·0
,, 10″ ,, ..	26·0	0·1	26·0	0·1
,, 14″ ,, ..	17·8	0·6	17·7	0·5
,, 20″ ,, ..	14·5	2·1	13·9	1·5
,, 28″ ,, ..	13·2	8·3	13·1	6·6
,, 35′ ,, ..	8·0	10·9	8·9	10·0
,, 48″ ,, ..	6·9	14·5	8·0	16·1
,, 65″ ,, ..	3·7	10·7	4·5	11·9
,, 100″ ,, ..	2·7	9.9	2·9	10·9
,, 150″ ,, ..	1·9	7·9	1·5	8·5
,, 200″ ,, ..	0·8	4·2	0·6	4·5
Thru 200″ ,, ..	4·0	30·8	2·0	29·4

The Chairman:—The passing of time makes it necessary for us to call the discussion to a close. I am sure, however, that any further questions, if put in writing, will willingly be answered by the lecturer to the best of his ability. I am sure you will agree with me when I say that we have had one of the most interesting evenings that we have ever spent in connection with the Ceramic Society.

Mr. H. S. Newman (communicated):—It is frequently raised as an objection to cylinder grinding as against pan grinding that the particle is more rounded than pan ground. Will not your mill produce spherical particles by reason of rubbing action taking place in the cone before discharge from the cylinder.

Mr. Farrant:—That cylinder ground particles are more rounded than pan ground is really a matter of opinion. Two well-known men in the Pottery profession, viz.:—W. Jackson and W. A. Lethbridge (Trans. English Ceramic Society, **2**, 5, 1902), endeavoured to find out by microscopical investigations any physical difference between the particles of pan and cylinder ground materials, but they were unable to do so. They further stated that all particles seem alike to possess irregular angular forms, and this, I may state, has been our experience when examining finely wet ground particles by both ball and pebble mills.

Mr. F. Carnall (communicated):—In the first place I should like to thank you for your very instructive lecture last night. I had a few questions I should like to have asked you, but time was over before I had the opportunity, so I take the liberty of writing and asking you to reply to the following:—

(1). In the case of glaze, which is a mixture of several materials in a given proportion, your continuous grinding cylinder, I take it, could not grind this, as the classifier would return the coarse material which most likely would be "frit," and so alter the constituents of the Glaze.

(2). I noticed that your model contained nuts and sawdust representing pebbles and materials, only *half filling the Cylinder*. Is this the correct proportion for efficient grinding? And does it not take more horsepower to drive than if say, $\frac{3}{4}$-full with pebbles and material (wet grinding).

(3). In grinding calcined and crushed flints, I find that after it is run off the cylinder into the ark that it settles, or the ground material drops, unless some "anti-set" such as china clay, etc., is added during grinding. Will flint ground on your Hardinge mill set, and if so how do you propose to add this "anti-set"?

(4). How do you allow for grinding away or wearing away of pebbles? Do you add say three to five pounds of pebbles to every ton of material ground, and feed into the cylinder with the material?

MR. FARRANT:—(1). With regard to the grinding of glaze, which is a mixture, as you say, of materials of different specific gravities in definite proportions, I am of the opinion that the closed circuit system of grinding would be unsuitable where only small quantities are required. I mention small quantities for a particular reason. If you will refer to my paper on grinding Mesabi iron ores, you will note the specific gravity of the component parts varied from 5 to 2·6, yet the final product from the classifier overflow was similar to the initial feed, but in order for this balancing to take place, it would require probably at least 24 hours grinding.

With further reference to the classifier, since the criticism I received at the meeting, and also observations I had made after my paper was written, I am of opinion that for very finely ground materials, the mechanical rake classifier is not suitable, because as the rakes lift, the fine oversize or knots slip down the incline into the overflow chamber. These would gradually accumulate, and the product would then become too coarse. I consider the hydro settler, which is somewhat similar in principle to your washing tubs, to be the better machine for the purpose of washing up.

(2). A most interesting question in continuous grinding. It has been our experience that the maximum amount of grinding is done when the cylinder is half full. Under these conditions the horse-power is also at a maximum. You obtain a longer drop of the pebble for a longer roll, and more pebbles are in action in a given time. A cylinder, as I noticed yesterday, when going through a cylinder mill, certainly absorbs less horsepower with a $\frac{3}{4}$ charge, or even a $\frac{5}{8}$ charge, but I doubt if it would be claimed, even in cylinder grinding in batches, that more grinding is done than when the cylinder is half full.

NOTE:—In order to charge a mill $\frac{5}{8}$ full of pebbles for continuous grinding, it would, of course, be necessary to place a coarse grating on the discharge end of the mill to prevent the pebbles from coming out.

(3). I think that there will be a settling tendency just as much with the Hardinge mill as with a cylinder grinding calcined and crushed flint. If this setting can be overcome by adding some "anti-set" it would seem to me to be most desirable to feed this in through the scoop feeder attached to the Hardinge mill, but the quantities would probably be so small that it would be difficult to apportion the amounts evenly.

To overcome the settling tendency, I claim it would be necessary to continually remove the knots as they drop to the bottom and return them to the grinding mill, either by an ordinary pump as used in the Potteries, or by a special Frenier pump, which is designed for this particular purpose of handling sludge. The advantage of the system that I described depends on its being entirely continuous and automatic, therefore, this settling tendency should be overcome owing to the continuity of circulation.

(4). If the consumption of flint pebbles is 5 lbs. per ton, and you are grinding say 10 tons in a 24-hour day, the consumption would then be 50 lbs. of pebbles. This amount of pebbles should be charged in at least once a day, or half the amount charged twice a day, in the discharge end of the mill while it is in operation. The opening of the trunnion is 10″ in diameter. They can also be fed in at the feed end through the scoop feeder, but this is not quite so simple.

In mentioning the wear at 5 lbs., I have given the highest figure which has been recorded, and I should like to know how this consumption compares with cylinder grinding.

While you have not asked the question, I should like to make a statement that I was surprised at the amount of material which would not pass a $1\frac{1}{2}$″ ring which you charge in. In pebble mills, this size of feed to a continuously operating pebble mill is entirely contrary to our (if I may say so) extensive practice. We consider that for good efficiency, the maximum size should be $\frac{1}{4}$″, because at this size it is estimated that a 3″ or 4″ pebble can crack this size particle at one blow, but to endeavour to crush a 2″ particle with a 4″ flint and to shatter it to atoms is an entirely different matter, and I contend that this is rather crushing work for the crusher than for the grinder.

XI.—The Marlow Gas-fired Tunnel Oven.

By. J. H. Marlow.

SOME 33 years ago I had the pleasure of seeing natural gas applied to the making of steel. This raised a question in my mind regarding the application of gas to firing tiles, pottery and other refractory materials. From that day to the present moment I have been working out schemes hoping to bring about the general use of gas for the above purpose. The result of my labours is the present Marlow Tunnel Oven, and I will endeavour to put before you a few of its varied details.

Many years of trials and struggles had to be gone through before I arrived at the present state of what I believe to be a perfect and entirely new system differing from all others, as you will see by following me and referring to the drawings I now have pleasure in placing before you. The researches I made proved to me, that in order to apply producer gas as a means of procuring heat for tunnel oven or other firing, I must first devise a simple producer, but an effective one; secondly, it was essential for me to have a system of pre-heating the air and superheating gases, before combustion took place; thirdly, the exhaust, which I claim to be the governing feature, must be of some kind that would draw the heat through the centre of the tunnel and not pull it along the walls.

These three essentials I believe I have brought into being, and they are now used in the construction of my tunnel, making it very easy to manipulate temperatures. 1140° Centigrade can be raised in the short period of 48 hours from the time of lighting the fire in the producer. Changes of, say, 100° Centigrade up or down, can be made in the space of 3 hours.

For some weeks past we have been firing glost ware at 1120° Centigrade 4 days per week, the other 3 days earthenware biscuit at 1180° Centigrade, and floor tiles at 1220° Centigrade.

This proves the general utility of the oven and its elasticity to comply with the different ranges of temperature required in the manufacture of the varied goods we produce at Messrs. Minton, Hollins and Co., where this tunnel is erected and giving the greatest satisfaction.

If you will now kindly follow the drawing, I will endeavour to point out to you the simplicity of its construction.

A. the firing zone.

B. the hot air reception chamber.

C. a duct through which the pre-heated air comes to meet superheated gases, *D*, in combustion chamber *E*.

F. a step chamber for the distribution of the products of combustion which pass the orifices *G*.

The first chamber contains sufficient products of combustion to supply the whole of the orifices. The reason for the steps 1, 2, 3 and 4, is to stop the gases from rushing to the end of the chamber and thereby to prevent a blast, each step only allowing sufficient gas to go forward to supply the orifice in front.

H. air pipes through which air passes to the air chamber *B*. From this you will see one of many ways by which the pre-heating of air is arrived at.

I. the cold air inlet through which air passes to supply the pipe chamber *J*. This inlet is at the ingoing end of the tunnel.

K. another air inlet from which the air is taken to keep the bottom of the carriers cool. You will notice that it travels through the zone, and at chamber *J* it descends beneath the flue fed by air inlet *I*, and at the outlet, is connected with the fan, thereby serving a double purpose. In the first place it becomes hot by keeping the carriers cool, and then becomes cool by pre-heating the air under which it passes before entering the fan.

N. what I term No. 1 combustion chamber, which is constructed outside the kiln, and by its utilization I have been able to raise the temperature so quickly. When first lighting off, the damper on the producer end is opened and the air is admitted through a small inlet which may be made inside or outside at will, but must be accessible so that it can be closed up.

This chamber is raised to a temperature of, say, 900° Centigrade. The object of this is to generate an excessive heat in a small space, the same permeating the wall, at the back of which you will see the air chamber *B*.

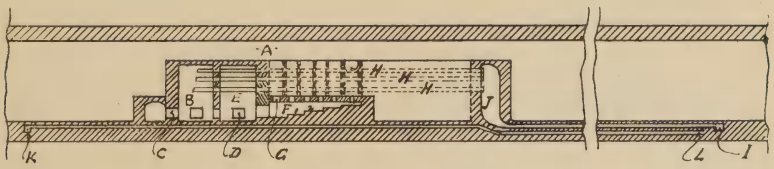
The air coming into *B* through *H* is now heated up and is ready to meet the gases coming through *D* which gives you almost perfect combustion. The gases coming through the orifice *G* play on the pipes *H*, through which the air is passing, into *B*, raising the temperature therein. The same now reacts on the partition wall, superheating the gases passing through the damper *N*, increasing their temperature from the time of leaving the producer by about 150° centigrade, before coming into contact with air coming through the duct *C*.

The exhaust is a system of pipes, and will be explained from the accompanying sketch.

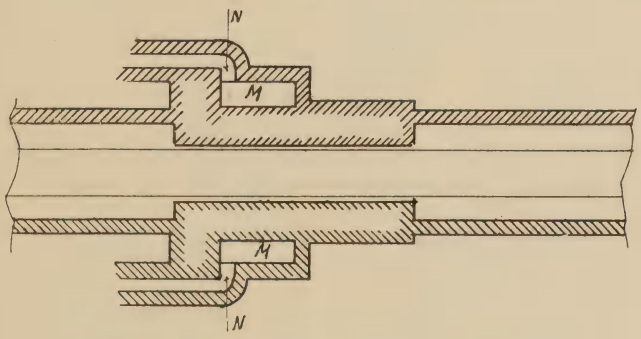
For every 2 ton 4 cwt. of coke used at the present time, we get 13 tons 16 cwts. of fired goods.

I might go on and say many more things about the Marlow Oven, but I will leave these over to a later date, at which I shall be very pleased to answer any questions that may be put to me.

Section at Exhaust.



Sectional Elevation thro' Heat Zone.



Plan.

DISCUSSION.

LT.-COL. C. W. THOMAS:—I am sure that we are all very much indebted to Mr. Marlow for the description that he has given us of his tunnel oven, and I am glad that he assures us that any questions that we may care to ask he will be prepared to answer within certain limits. Whether or not he will be able to answer all the questions that we may ask will depend entirely upon their nature. I think it would have been an advantage if we could have had the drawings before us for some little time in order that we might have examined them more closely. It is rather difficult

to see at a distance the exact details of the kiln. I, personally, was very much interested in Mr. Marlow's statement that the general arrangement of the kiln and its method of working amount almost to a reversal not only of common practice but of theory. I would rather have liked Mr. Marlow to trace that point through. However, it may come out in the course of the discussion.

Dr. J. W. Mellor:—I would like to congratulate Mr. Marlow upon his industry and bull-doggedness. I have admired the plucky manner in which he has persevered in his work, in spite of his having received very little encouragement from others. He has said to me on several occasions that his kiln contradicts theory; and that theory is all wrong. I would like him to give us a clear statement of the points in regard to which he contends that the work he has done is contrary to theory—either as applied to gas-firing as a whole or any part of it. If he can show that the theory is wrong, then I think he will deserve more credit for that demonstration than for his success with the kiln.

Mr. Marlow:—I believe that theory says that you should never rob heat to make heat—that you should not bring cold air through a hot zone and expect to attain to the greatest temperature thereby. Nearly all who have studied my kiln have said to me—"You are absolutely wrong: You are taking in the air from the wrong end. You are robbing the heat zone of its heat." My reply has always been: "I take 10 per cent. in order to gain 50 per cent. Therefore, in the end, I gain." My critics have replied: "That may be, but you are wrong all the same." Certain manufacturing potters, who have examined the goods which the oven produced, have likewise said: "The goods are all right, but the system is all wrong." My point is that I am satisfied with the goods being right, and so long as I can attain to that I do not care two straws whether the system is theoretically right or wrong. I take the air from the in-coming end, and pass it right through the zone of the tunnel from which I expect to get the pick of my heat. The heat brings the air through, and the fan takes it back again through the tunnel in which it meets the gases, and combustion results. It is because of this that I am able to raise the temperature so quickly. If you were to go to my pyrometer now, although I am 150 miles from where my oven is situated, I will guarantee that I could tell you within five degrees the temperature that the oven is recording, simply because it gets its heat from the heat that it makes, and does not depend upon any ebbs or flows of air coming in from the outward end. It is because of this that I say my practice is contrary to theory. To those of you who may be interested in the old bottle-shaped oven I would say: What would you give if you could take the heat that you do not want over the bags and conduct it right to the centre of the oven, thereby equalising it? It has been the inability to do this which

has been the bugbear of pottery firing in the past. I claim to have overcome that, and that I am able to take the heat from where I do not want it and transfer it to the point at which I require it most.

DR. E. W. SMITH:—I think that probably Mr.Marlow would agree that a better interpretation of what he intends to say is that his system is contrary to *accepted ideas* rather than contrary to *theory*. I should say it is quite conceivable, unless he has had taken for him a comprehensive chemical balance sheet of the constituent gases right through every stage, that there are explanations other than the one he indicates as to why he gets the temperatures that he does get. I would not suggest though that his idea is wrong. It is quite possible that in taking away a certain amount of heat from the zone in which you want your higher temperature you are using that heat in a more efficient way by getting an increase of heat. That, however, has not yet been proved. As I say, it is quite conceivable that there are other explanations than those which Mr. Marlow indicates for the results which he has obtained. Unless he has had a complete examination of the kiln at every point—a clear determination of the efficiency of the kiln at every point, as well as of the composition of the waste gases, the unburnt gases and so forth— he has not yet attained a really definite idea of what it all amounts to.

MR. P. J. WOOLF:—As a left-handed compliment to Mr. Marlow, I may say that about a year ago I fought the Lignite Utilisation Board of Alberta and Ottawa in Montreal, on this particular point. Their engineers in the two places mentioned were coking lignite, and were robbing the heat of the combustion chamber in order to secure correct combustion. Incidentally they claimed to secure a more even temperature thereby. I endeavoured to persuade them that they were wrong, but I failed. The method that I suggested was to rob the heat from the exhaust gases. I have no comment to make beyond stating that I figure that my theory was right, although the Lignite Utilisation Board decided that their engineers were right and that I was wrong.

MR. JOHN P. LEATHER:—I think the point at issue is that it is not absolutely necessary to get the *highest* temperature, but that you want to get the *right* temperature. That being so, it may be quite the right thing to heat the air from the highest point of the furnace. So long as the temperature is just what you want, I imagine that you must be getting the most efficient heating.

MR. MARLOW:—Into the zone of the oven I let all the cold air that I possibly can, consistent with other arrangements that I make. Theoretically I am wrong there, because the natural tendency would be for that to rise and to reduce the temperature at the top of the oven. It does not do that; on the contrary it

forms a vacuum which enables you, if you wish, to reduce or to lengthen your heat zone by about 9 feet. I admit that this is somewhat strange theory, but I can prove it in practice.

In reply to Dr. Smith's query with regard to the heat examination of my oven, I may say that this has been carried out, and that it has been ascertained in six tests that we had CO_2 14·6 four times and CO_2 14·4 twice. Three or four days elapsed between the taking of the various tests.

I may add that any gentleman interested in the firing of clay wares is at liberty to send in ware to be fired in my oven. I am open any week-end to fire from 1,000 to 1,300 degs. C., and the works are open for anyone to go and see the oven by appointment at any working hour. I repeat also that I will undertake to tell you within five degrees at any time what the pyrometer of the oven is recording.

Sir Arthur Duckham:—Mr. Marlow has told us of the effect in a tunnel oven of the segregation of the heat to the centre. He says there is a flow to the centre of the tunnel oven; that there is a clear passage on the sides between the cycles of the smoke cloud and the strut down the centre; and that there is a free wave on the sides. I presume it is a closed tunnel oven and that the heating is done by radiation and not by convection. In other words, it is a muffle oven, and therefore there is no real passage of gas or air through the oven except by means of the end doors.

Mr. Marlow:—Oh, yes. I put the air right into the oven.

Sir Arthur Duckham:—So you do get a passage of air right through the oven and not like an oven that is closed. Do the products of combustion and the air both come into contact with the goods?

Mr. Marlow:—Yes.

Lt.-Col. Thomas:—I think what Mr. Marlow has just said proves that he is opposed to theory as well as to practice. I doubt very much whether anyone could say within five degrees what any particular pyrometer is recording at any particular moment. Such a claim is certainly startling.

Mr. Marlow:—I agree, but I still persist in the claim.

Lt.-Col Thomas (continuing):—It is an ideal that we have all, at one time or another, pictured for ourselves, and hoped that we might attain to. I do not know quite whether the average clay-burner has lent himself to the same ideal. I should think probably not. There was one point that occurred to me whilst Mr. Marlow was speaking. It is quite conceivable that in certain instances it may pay to take some of the heat either from the producer or from the highest point in the zone of combustion, and

to utilise that for preheating the secondary air, simply because you have an excess of heat there. It has been extremely interesting to hear Mr. Marlow's description of the oven, and I have no doubt that there may be some members present who may like to avail themselves of the opportunity of having some of their ware tried through Mr. Marlow's kiln.

To me one of the most valuable features that Mr. Marlow has mentioned is the fact that he is able at comparatively short notice to raise or lower the temperature of the combustion zone by a considerable amount. This would overcome to some extent a difficulty that I have always foreseen in the adaptation of a tunnel oven to the firing of refractory wares. One knows perfectly well that you cannot fire big ware—blocks weighing a hundredweight and so forth—at the same rate as the ordinary 9″ or 3″ bricks. Therefore, for a tunnel oven to be adaptable for the general run of an ordinary refractory works, you have either got to slow it down when you have big ware coming through, or else you have to take the other alternative of having more than one tunnel oven, each of them being speeded for different thicknesses and different sizes of blocks. If Mr. Marlow is able to vary the temperature in the way that he indicates, presumably he would be able to vary the speed at will, and be able to run several cars of big blocks, followed by several cars of smaller blocks, thus suiting the kiln to the varying exigencies of the works. If he can do that, he is offering us a rather valuable feature.

Mr. Marlow:—That is exactly the position. I would vary the speed by means of an accelerator. If you will bear with me for a moment I will show you another point that I have embodied in my tunnel—a feature for which I received the patent only yesterday. The temperature of a pottery oven goes up in a series of angles—a forward movement and a rest. There is a slight retardation every time you bait. Now that resting time, if one may so describe it, has been said to add to the beauty of many of the goods that potters fire. It is well-known that, in the old intermittent system of firing, the heat of the oven went up by a series of jumps such as I have described, whereas, in the ordinary tunnel ovens, the heat goes up very gradually. The latter result is not always satisfactory when applied to pottery firing. The old system, necessitating a rest after every baiting, has certainly given in the past some of the most beautiful pottery that one could wish to see. I have been working on this point for some time, with a view to getting in my tunnel oven a corresponding result. I have applied myself to the problem very directly during and since the coal strike. During the coal strike I was able to put an idea to the test. It proved quite satisfactory and, as I have remarked, I have since patented it. The idea consists in the building of a series of baffles which come within 4″ of the carrier.

As the carrier passes along the rails it encounters the resting time when it gets into the wider spaces of the tunnel wherein the heat opens out. In this way the heat is squeezed in and out concertina fashion. Many of the imperfections that we at first encountered with tunnel firing have been absent since this system was introduced, and I think it comes nearer to the old system of firing than anything that has yet been put before you.

XII.—Combustion of Fuel Oil; with a Description of an Oil-Gas Furnace.

By Percival J. Woolf.

Definition and Object of Combustion. Combustion is generally defined as the chemical union of any substance with oxygen, generally the oxygen of the air. By chemical union is meant molecular combination. The object of combustion is generally to obtain temperatures for heating or power purposes. The higher the temperature, as a rule, the greater the effectiveness of the heat.

Temperatures. In any combustion process the rising temperature is effected primarily by :—

(*a*) The heat energy in the material burned.
(*b*) The total quantity of the products of combustion.
(*c*) The dilution of the products of combustion with neutral material.
(*d*) The confinement of the space of combustion.

The above items may be emphasised and illustrated further in the same order as follows :—

(*a*). A pound of carbon yields 14,500 B.T.U. A British Thermal Unit is that quantity of heat which is required to raise one pound of water one degree Fahr. A pound of carbon has potentially the power to raise 14,500 pounds of water one degree Fahr., or a smaller quantity of water to a proportionally higher degree. A pound of hydrogen yields about 60,000 B.T.U., and therefore has potentially a higher value as a heat-producer.

(*b*). Considering further the examples under item (*a*), and assuming that the heat generated by combustion is not transferred, that is, the materials of carbon and hydrogen are each respectively burned in an insulated chamber, and the resulting heat goes toward raising the temperature of the products of combustion alone ; it would appear at first glance that the temperature of the hydrogen combustion product would be higher than the temperature of the carbon combustion product. That, however, is not the case, and in spite of the great difference in the amount of energy evolved, the temperatures reached are approximately the same when the products of combustion in each case are held under the same pressure. The essential difference lies in that one pound of carbon required 2·67 lbs. of oxygen, whereas one pound of hydrogen required 8 lbs. of oxygen, making the products of combustion much greater with hydrogen than with carbon. The heat energy must be distributed, therefore, amongst the larger quantity of material in the case of hydrogen than in the case of carbon.

(*c*). The examples given in items (*a*) and (*b*) indicating a union of carbon and hydrogen with oxygen, are ordinarily carried out by supplying air in place of oxygen. Air contains by weight 23% oxygen, and the balance, or 77%, is almost entirely nitrogen,

a neutral element. In place, therefore, of supplying $2\frac{2}{3}$ lbs. of oxygen, it is necessary to supply, to get that amount of oxygen, about $11\frac{1}{2}$ lbs. of air, and for hydrogen about $34\frac{1}{2}$ lbs of air. The products of combustion, including the fuel itself, when accurately combined, is therefore in the case of carbon $11\frac{1}{2}$ plus $1, = 12\frac{1}{2}$ lbs., and for hydrogen $34\frac{1}{2}$ plus $1 = 35\frac{1}{2}$ lbs. The total heat yielded by a pound of carbon must be divided into the weight of the total products of combustion, or $12\frac{1}{2}$ lbs., and each pound of products will contain—

$$\frac{14{,}500}{12{\cdot}5} = 1{,}160 \text{ B.T.U.},$$

and for hydrogen—

$$\frac{60{,}000}{35.5} = 1{,}690 \text{ B.T.U.}$$

(*d*). Combustion carried on by introducing fuel and air into a chamber of fixed closed space brings about a different result in temperature than combustion taking place either in the open or inner chamber that has free openings to the atmosphere, so that when expansion due to heat takes place, the gases may escape outward. In a confined chamber, such as an internal combustion engine, where, during the period of combustion, the gases are confined, there results an increased pressure and with it an increased temperature.

Separating Air proportioned in Practice. The proportion of air required for complete and exact combustion of any fuel is, as indicated above, fixed. Ordinarily, however, in the majority of the methods of combustion, it is not possible in a practical way to maintain this exact ratio. Generally, the quantity of air introduced is much in excess of that required for exact combustion, and on this account the temperature is further affected by the dilution of the products of combustion with the excess air. For example, it is well known that in the burning of coal under a boiler, from 60% to 100% excess air is used. This excess of air is due to the attempt at burning solid fuel with air, which is a gas. Likewise, in the burning of other fuels, such as fuel oil, which is a liquid, even when sprayed in the form of a mist by the ordinary method, excess air is required because of the inability to mix readily liquids and gases.

Mixing. The mixing of gases with gases is readily and almost automatically accomplished, and the burning of gaseous fuel with air can therefore be controlled in a very exact manner as to proportion. On the other hand, the burning of fuel in the form of liquids or solids is not so controlable, because of the difficulty of mixing properly solids and gases in any intimate manner. Any method, therefore, by which the fuel is converted into the finest state, which is gaseous, perfects its combustion with the greatest control and best proportion, and eventually with the most advantageous results from an economic standpoint. Mixing is therefore the basis of proper combustion, and the gasification of the fuel permits the best possible mixture.

Conversion of Fuel into Gaseous Form. The principal commercial fuels, apart from gases, are :—

(*a*) Coal.

(*b*) Petroleum and its products.

The conversion of coal into gaseous form prior to combustion has been developed in several ways, the best known being the Producer Method, which is used largely in connection with open-hearth furnaces. The open-hearth furnace is in itself an expensive piece of apparatus, as the gas-making apparatus forms a considerable portion of the complete installation. In such furnaces the gases are conducted directly from the producers into the furnaces in the hot form. For other industrial purposes where small furnaces are used, it has not been found practical to utilise either hot producer gas, or, in many cases, the regenerating principle for heating the air supply. The principle employed in the producer is that of forcing the blast of air, and with it some steam, through a deep bed of coal in a container, producing partial combustion within the bed of coal and distilling off through the heat-generator the voluble portion of the fresh coal above. This gas usually leaves the producer at temperatures ranging from 1,200 degrees to 1,500 degrees Fahr.

The conversion of petroleum into a gaseous form exterior to the combustion chamber, has been accomplished very readily by means of an air-blast for the lighter liquids, such as naphtha, as in the application to gasoline engines. Petroleum fuel products of the heavier kind have been utilised in the gaseous form by a distillation process, or by what may be called the boiling process. Where the heavier oils are used, the distillation process produces a residuum, so that all of the fuel is not utilised directly. Where the rate of consumption of the gas is not concomitant with the rate of production or distillation, a container must be furnished to take care of the difference. It is apparent, therefore, that the conversion of coal, or heavy petroleum products into gaseous form, involves expensive apparatus beyond the equipment required to consume the gases. Any method by which the conversion may take place immediately or within the furnace in some simple way, has direct advantage. Preferably a method of conversion that is automatic, requiring no removal of residue, and a method with which no hazard is connected, is obviously most desirable. Incidentally, any method of utilising this gaseous fuel must also be free from such detriment as excessive oxidization. And in addition to the above, economy must be an important factor of such method.

Fuel Oil. This discussion deals primarily with the combustion of fuel-oil. Fuel-oil is the residue of petroleum oil, after lighter products, or naphtha, have been removed. Ordinarily, fuel-oil contains by weight about 86% carbon, 12% hydrogen, and the balance, or 2%, other material, such as sulphur and ash. The above proportions vary only slightly with the different grades and sources of fuel-oil. The percentages of carbon and hydrogen being

approximately uniform, it was to be expected that the heat-value per pound of fuel-oil would not vary a great deal. This has been found to be the case, and this heat-value ranges between 18,500 and 20,000 B.T.U. per pound.

Crude oil and petroleum oil being the source of fuel-oil, the latter has characteristics depending upon the scource and treatment of the crude oil. For example, the crude oils of the Eastern States are lighter in specific gravity and are more fluid than the crude oils of the South-Western States, and particularly the Mexican oils. Fuel-oils are likewise affected by a variation in density ranging from about $7\frac{1}{2}$ lbs per gallon for the Eastern oils to about $8\frac{1}{2}$ lbs. for the South-Western fuel-oils. Also the Eastern fuel-oil, like the crude, is reduced to a fluid at ordinary temperature, but slightly more viscous, and in winter temperatures the viscosity increases so that it does not flow readily through piping unless under considerable pressure. Experiments carried out with some fuel-oils indicate that below 200 degs. C., the quantity that is vaporized is negligible, and that between 200 degs. C. and 300 degs. C., only a small portion of the fuel-oil can be vaporized. When raised to a temperature of over 300 degs. C. the fuel-oil commences to vaporize more extensively, and when 400 degs. C. is reached it is substantially vaporized. At 450 degs. C. it has been found that it is completely vaporized except for a minute quantity of solid, this quantity being under one per cent.

Separating Burning Fuel-oil by Spray Method. Fuel-oil when poured into an open vessel and lighted, will burn with difficulty and such burning will go on sluggishly, forming a heavy dense smoke with a slight dull red flame of moderate temperature. In that condition the air is not able to mix with the oil and the combustion is very slow. As indicated above, fuel must be mixed intimately with air to effect satisfactory combustion. The earlier methods of burning fuel-oil utilised the oil in the form of spray. A fine spray surrounds itself with considerably more air and is mixed more intimately than when the oil is in bulk. Several methods have been utilised for spraying the oil, all involving practically the same principle, viz.: that of putting the oil under pressure, ejecting through a fine orifice and supplying at the same time a current of air generally crossing the stream of oil, and thereby breaking the oil up into a spray. Pressure is required both on the oil and on the air to accomplish the spraying, and in order to carry this mixture into the combustion zone of the furnace, the mixture must be given velocity sufficiently high to carry it over for the distance required without permitting the oil to drop down and separate itself out from the mixture with the air. For this purpose, velocity becomes an element in maintaining the mixture for combustion. This method of spraying has wrongly been called "atomizing." While the particles of oil thus sprayed in may be very fine and float readily for a while in the air current, they are, nevertheless, millions

of times larger and heavier than the individual molecules of oil, and such particles of oil are very dense masses as compared with air molecules.

It is evident that no matter how fine a mechanical oil spray may be made, it will not mix as thoroughly and intimately with the air as when such oil is converted into a real gas. Combustion, therefore, is not as rapid when oil is sprayed in as when it is introduced in a gaseous form. The result is that with a spray method combustion lags, that is, it does not take place immediately after entrance into a combustion chamber. In very large furnaces the stream of the mixture will travel several feet before ignition takes place. That part of the furnace next to the entrance of the mixture is inert as far as combustion is concerned. In smaller furnaces the stream travels until it strikes an obstacle, such as the walls of the furnace on the opposite side, and is then checked in velocity. It is mixed through the impact, and the oil is then partly vaporized by coming in contact with a hot wall or brickwork, and combustion then starts accordingly. On this account it is frequently seen that combustion takes place against one side of the furnace.

It may be stated in general, that in the burning of fuel with a spray, a time element exists which is very small; by the end of this time, the mixing and ignition takes place. As the velocity required to inject the mixture is quite high, that is, usually 200 to 500 ft. per second, it is obvious that in a small furnace of one or two feet or even somewhat greater in length, the mixture will reach the opposite end of the furnace within an exceedingly small fraction of a second, generally in not sufficient time to permit complete combustion after ignition has taken place. The common observation is, that where an outlet from the furnace is available, the high colored flame emerges from the furnace and combustion is completed after the mixture has left the furnace. It is obvious that combustion that takes place after the fuel has left the furnace is of no value. The important task, therefore, is to confine within the combustion or heat chamber the fuel and gases until the combustion is complete and has yielded up part of its energy towards heating the furnace and its contents. Within the exceedingly short time allowed, it is therefore important that the mixing of the fuel and air be given special attention, so that the combustion will take place when and where desired. In the spray type of furnace this combustion is accelerated by inducting an excessive amount of air with the fuel, so that combustion will take place more rapidly, or by an elongation of the furnace to allow greater time for combustion. This excess of air supplied for the purpose of rapid combustion and for the elimination of smoke, has its drawbacks, which can be gathered from the first paragraph, viz.:—

(*a*) Lower temperatures are obtained with excess air.
(*b*) Lower heating results on account of lower temperatures.
(*c*) It takes more fuel because of the lower temperatures.

(*d*) The excess air furnishes an oxidising agent, which in metallurgical furnaces is objectionable.

The prime reason for introducing excess air is, as noted, to obtain more rapid combustion and avoid smoking. It would appear, however, at first glance, that an exact amount of air would be sufficient for operation. Several factors occur in a spray method which prevent this, viz., when air and oil are simultaneously injected into a furnace at a velocity, resistance to this flow is met with in the gases within the furnace. The air, being light, loses in velocity very rapidly. Oil, on the other hand, even though in small particles, being approximately one thousand times as dense as the air, has greater momentum and loses less in velocity than the air. In other words, if the mixture has travelled a distance into the furnace, the oil, due to the greater velocity, separates itself out in part from the air medium surrounding it, and travels on. In order that this oil may have a sufficient quantity of air to burn in after it has travelled some distance, an excess of air must be supplied so that the farthermost part of the furnace from the inlet of the mixture will have a sufficient quantity of air to burn the oil. The near part of the furnace, that is, adjacent to the inlet, has therefore the largest supply of excess air. This excess air in the furnace absorbs the radiation heat reflected in the furnace, thus lowering the average temperature. In contrast with liquid fuel, when gaseous fuel is injected with a mixture of air into a furnace, the mixture is not only thorough, but of such a homogeneous nature as to avoid separation due to any resistance against the current.

Velocity. It will be seen from the foregoing that velocity is an important agency required in the combustion of fuel-oil and similar fuels. Specifically, velocity is given to the injected air so that—

(*a*) It will break up the stream of fuel that is introduced in its path into a fine spray;

(*b*) And will permit the floatation of the small liquid particles of oil in the spray without permitting this oil to drop downward. The carrying capacity is in proportion to the high power of the velocity.

(*c*) The velocity in some applications is due to an auxiliary current which floats in along with the stream under pressure. This latter is utilized in what is known as the high pressure burner, wherein a small part of the air is under pressure, and the balance is induced from the atmosphere through an opening immediately surrounding the burner.

While velocity is created for the purpose of assisting in the combustion of oil, it has also its disadvantages which may be pointed out as follows:—

(*d*) It tends to carry the fuel mixture towards one end of the furnace.

(*e*) It takes part of the fuel out of the furnace before combustion takes place.

(*f*) It causes strong impingement of the liquid particles against the wall of the furnace, resulting in a washing effect, and the rapid deterioration of the brickwork.

(*g*) Unequal heating in the furnace results in consequence of the unequally distributed combustion.

Combustion Chamber. As a remedy for some of the foregoing difficulties met in connection with the spray method of burning oil, the most common method that has been adopted is the addition of a combustion chamber to the furnace, separate and more or less distinct from the heating chamber. The effect is mainly to divide the furnace into two sections, one in which the combustion is started and the other in which the combustion is finished and also in which the heating effect is more uniform. To get the proper results, such a combustion chamber should be about one-third the size of the heating chamber. The advantage of a combustion chamber is mainly for better distribution of heat, and for a somewhat reduced oxidisation effect. The disadvantages of a combustion chamber separate from the heating chamber, are:—

(*a*) The heating is accomplished not at the highest temperature of the combustion chamber, but at the secondary temperature, lower than in the combustion chamber, which is maintained in the heating chamber.

(*b*) The furnace is increased in size by about one-third and with it the standby losses are clearly increased. The insulation of the combustion chamber, maintaining a localized high temperature that is not subject to cooling, results in rapid deterioration of the brickwork. This leads to what is commonly known as "hot box."

Vaporizer Method. To eliminite the excess air in burning oil, and at the same time obtain perfect combustion within the furnace proper, without increasing the size of the furnace or adding to it in the way of combustion chambers, the vaporisation and mixing of the oil and air prior to the entrance into the furnace, has been accomplished by the Sklovsky U.S. Patent No. 1,229,338. In this case the air is supplied under pressure, is forced through heating chambers which utilize the heat from the incoming gases, and is further forced from the heating chambers through a vaporizing chamber. Through the inlet the necessary fuel oil is supplied into the latter chamber, the oil being introduced into a stream of heated air; it passes through the vaporizer, together with the air, from which it absorbs the heat. By the time the exit of the vaporizer is reached the oil is completely vaporized and intimately mixed with the air, from which point it is conducted through a tube directly into the combustion chamber of the furnace.

In this patent the air is maintained at not less than 300 degs. and not over 450 degs. C. Preferably, the air should be 350 to

400 degs. C. The tube connecting the vaporizer to the combustion chamber is so proportioned that the velocity of the mixture through it will be sufficient to prevent a recession of the flame from the combustion chamber back into the tube and into the vaporizer. The result is that the combustion takes place immediately upon entrance into the combustion chamber, a uniform temperature in the combustion or heating chamber being therefore maintained. The mixture burns with the exact amount of air chemically required, and gives higher temperatures within the furnace and consequently more rapid heating. Incidentally, the combustion chamber being uniformly of high temperature, is smaller in size, and on this account has a low radiation surface through the exterior. The absence of excess air diminishes the oxidisation effect on the material.

"OIL-GAS" CONTINUOUS COMPENSATING FURNACES OR TUNNEL KILNS.

Long ago the cost of fuel forced European manufacturers of ceramics, and others, whose processes required long sustained application of heat, to seek more efficient methods than the usual batch or periodic furnace or kiln offered.

The earliest efforts were directed towards conserving the heat stored in the periodic furnaces after the treatment of the charge, by a partial transfer of this heat to another periodic furnace in process of heating up. This led to the ring furnace, where the heat successfully progresses from one furnace to another, the combustion air being heated in a furnace just past its high heat state and the products of combustion preheating a furnace in preparation. Thus a succession of furnaces is heated from one source.

The step to a stationary heat source and a succession of charges of stock passing through the various stages of the heating and cooling process, followed naturally. Thus the development of the "Railway Tunnel Kiln" or Continuous Car-type Furnace was due to the necessity for conserving fuel. All of the successful furnaces of this type introduced in America during the past decade, originated in Europe where fuel is and has been expensive.

So far as we know, the only truly American furnace of this type, which has demonstrated its success, has been produced quite recently by The General Combustion Company under the Kirk patents. The development of this "Oilgas" Compensating Furnace is based on long and intimate experience with the single chamber type of furnace, and the result is a furnace of extremely simple design in which are embodied all the excellent virtues of the best of the old types of furnaces without including any of their delicate features, and yet improving the economy and reducing the floor space required.

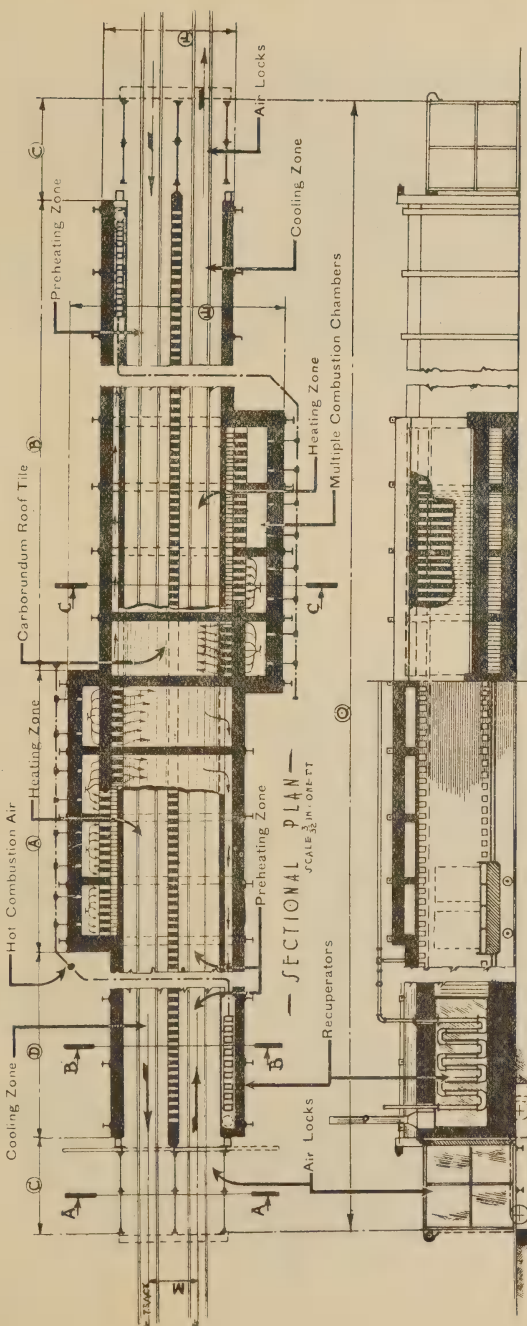
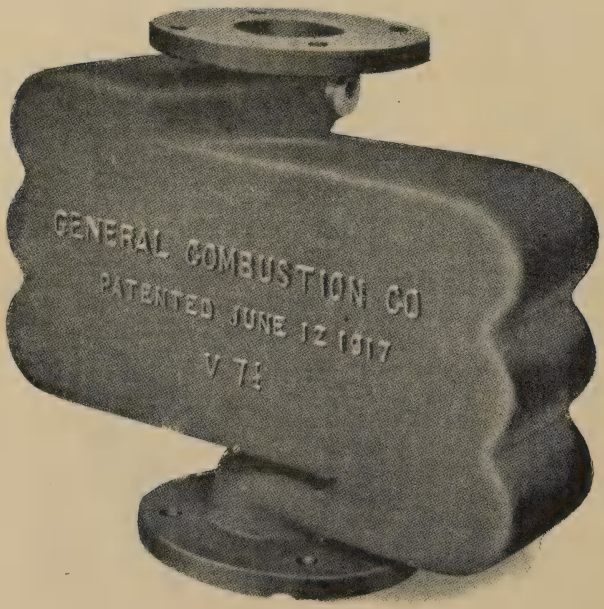

Hot Combustion Air
Heating Zone
Carborundum Roof Tile
Preheating Zone
Air Locks
Cooling Zone
Heating Zone
Multiple Combustion Chambers
Cooling Zone
Preheating Zone
Recuperators
Air Locks
— SECTIONAL PLAN —
SCALE 1/8 IN. ONE FT
ELEV. OF CENTER WALL
SEC. THRU COMBUSTION CHAMBER
— ELEVATION —
ANTE-CHAMBER & HEATING DUCT

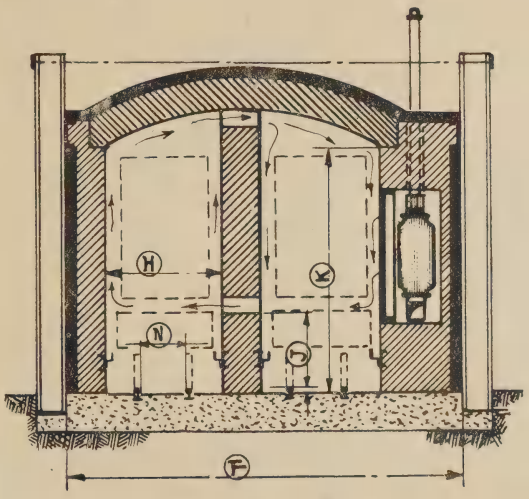
FIG. 1.

Air Heater



Vaporizer.

The "Oilgas" Compensating Furnace is a twin chamber furnace, in which the stock progresses through the two chambers in opposite directions. The treating zone is near the centre; thus a single source of heat supplies both chambers, and the entering cold stock is preheated by the treated stock enroute to the exit. The efficiency of this heat transfer is dependent upon the natural convection currents set up in the inert atmosphere of the furnace by the heat radiated by the charge.



— SECTION B B —

FIG. 2.

In the sectional view (Fig. 2) the left chamber contains a heated charge; the convection currents are therefore upwards. No heat transfer would be effected, however, were not the central wall perforated at the top to permit the hot rising air currents to escape. Upon entering the right chamber, and there encountering a colder charge, the air currents are cooled and fall rapidly to the bottom of the chamber, where escape is again provided through the central wall, to the heated charge. Thus a simple heat engine of great power and efficiency is utilised throughout the preheating and cooling zones, to accomplish several desirable ends:

(*a*) To preheat gradually the charge.
(*b*) To cool gradually the treated stock.
(*c*) To equalize the heat throughout each carload of charge.
(*d*) To prevent local over-heating.
(*e*) To prevent local cooling at too rapid a rate.

All this is accomplished without the necessity for any outside agency, such as water-cooled fans or wrought iron cooling or heat transfer pipes.

The treating zone (Fig. 1) is heated by the products of combustion from external combustion chambers, one or more of which are located on opposite sides of the furnace, but without intercommunication. The hot gases pass upwards through flues in the side walls, closed to the treating chamber by hollow carborundum tile, thence across both chambers through transverse flues formed of carborundum tile (Fig. 3) to a longitudinal flue, where for the first time the gases, having served their usefulness, are permitted to escape in the direction of the *incoming* stock.

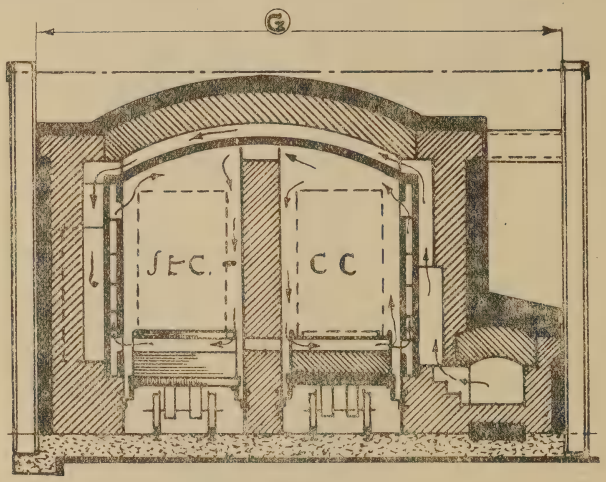


FIG. 3.

It should be carefully noted that the products of combustion travel directly across the axis of the furnace instead of parallel thereto, and that a multiple of combustion chambers and cross flues are provided, thus positively insuring a definite controllable zonal heat distribution. This is one of the most valuable features of this type of furnace, and constitutes a distinct advance in the art. By this means any desired heating can be provided with surety, and the heating curve can be changed at will to suit varying kinds or conditions of stock.

Before the spent gases are permitted to escape they are forced to yield up the last useful degree of heat by a final radiation section, where alloy plates are substituted for carborundum tile and "Oilgas" recuperators preheat all the air for the combustion system.

It will be noted from the arrows (Fig. 1) that the incoming stock is heated by the outgoing hot stock by heat transfer through the central wall and also by the spent gases passing out along the side wall. The internal convection currents insure even distribution of all the heat from whatever source. The charge is never sub-

jected to direct flame action ; in fact, the muffle is so perfect that all heating operations, except bright and gray annealing of steel, may be successfully accomplished without the use of containers or saggars.

Economy. The economy of the "Oilgas" type of furnace is inherently higher than any other type of furnace, for two reasons :—

(*a*) A large proportion of fuel consumed in any good furnace of this character is required for radiation losses. Since the "Oilgas" Compensating Furnace is only half the length of any single chamber furnace and no wider than the best of the single chamber types, the radiation loss for a given quality of wall construction will be one-half that of the older type of furnace.

(*b*) Since the heat transfer from out-going hot stock to the incoming cold stock is directed by convection currents over and under the central wall or screen, the efficiency of this heat transfer is far greater than for single chamber furnaces where the heat from the out-going stock must be transferred through pipes, water-cooled fans, and similar devices, to the cold end of the furnace two or three hundred feet distant.

Practically no heat is lost through the car bottoms due to the use of effective continuous seals. This is evidenced by temperature tests and by the non-burning of the lubricating oil on the roller bearings of the cars. No elaborate system of air cooling is necessary for the bottoms and bearings of the cars because no heat is permitted to escape. Concrete evidence of economy includes an actual run where the percentage of fuel (coal equivalent) to charge treated was reduced to $2\frac{1}{2}\%$.

The use of carborundum tile greatly facilitates the flow of heat through the flue walls.

The use of air locks, at the ends of the furnace to charge and discharge the cars, serves to avoid any longitudinal disturbance of the inert furnace atmosphere. This fact, together with the entire absence of cooling by drawing outside air through the furnace chamber, explains the remarkable freedom from scaling in annealing metals.

The "Oilgas" Compensating type of furnace is adaptable for any long continued heating cycle, for such purposes in the ceramic arts as bisque and glost firing of china and earthenware, sanitary pottery, etc., firing of building, paving and fire-brick, terra cotta and floor tile, annealing sheet steel, punchings, drawn steel wire, steel and iron castings, malleabilizing, etc.

In the brick industries large savings are possible due to reduced handling of materials, as water smoking may be done and the stock passed in through the burning zone, cooled and taken to the cars or storage without further handling.

In one plant in the United States, annealing sheet steel, a reduction in fuel from 47 to under 6 gallons of oil per ton annealed

has been accomplished, and with a product improved in quality.

In applying the "Oilgas" Compensating Kiln to the ceramic arts, the dimensions of the saggars and the cubic contents of ware that may be packed in each saggar must be determined before a suitable furnace can be laid out. Certain classes of pottery car furniture are preferable—being more economical of space. After determining the weight per saggar and the number of saggars per car, the total length of the furnace is fixed by the time cycle. For a continuous ceramic furnace, this is many days less than is required by a periodic furnace, since the comparatively small amount of charge per car can be heated much faster, and since no allowance need be made for cooling a great mass of furnace brick work, before workmen can begin drawing a charge.

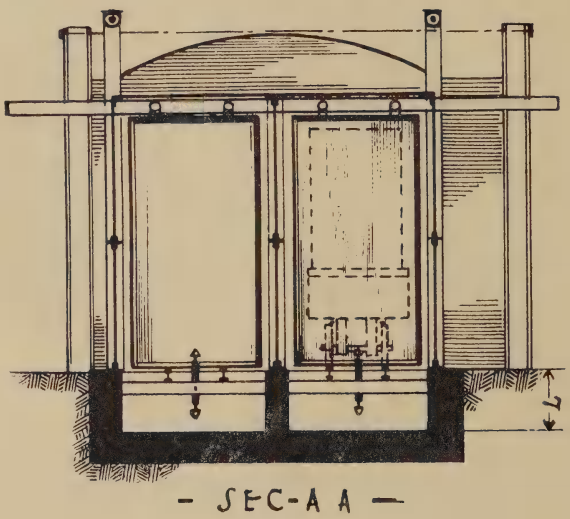


FIG. 4.

A careful study of all the conditions surrounding the manufacture of ceramic ware reveals the following advantages of the "Oilgas" Compensating Ceramic Kiln:—

1. Large saving in space, at least 50% less than any other tunnel kiln, as practically all fine china gloss and bisque can be fired in a furnace not over 100 ft. in length. Existing buildings can be readily utilised.

2. Reduction in fuel cost. The greater bulk of the heat in the off-gases is absorbed, as all the discharge gases go off at a temperature not in excess of 300 degs. Cent. The cars with their material also are discharged from the furnace at this or a lower

temperature. The radiation losses are half those of any other tunnel kiln.

Fuel oil can now be purchased for £3 : 17 : 6 per ton, and any kind of oil which will flow can be utilised.

3. Labour is used to better advantage, practically no attention being necessary for the furnace. No ashes or coal to handle.

Oil is easy to secure and easy to store. One month's supply can be stored in two tanks measuring 30′ × 9′.

4. Easier temperature control. You can run this furnace with a variation of less than 10 degs. in the combustion zone.

5. Cleaner and better atmosphere in the furnace rooms.

6. No stacks are necessary on oil-gas kilns, but we suggest a small pipe to carry off the spent gases.

7. Absence of exhaust fans to transfer heat. A fan is provided for the air necessary for combustion.

8. Flexibility of output. Gloss and bisque can be fired in the same kiln.

9. Improved ceramic practice, as all stock can be treated precisely alike.

10. The kiln being shorter, dangers due to cars leaving the track or furniture becoming displaced, can be more readily adjusted or rectified.

DISCUSSION I.

(London Meeting, October 6th, 1921.)

Lt.-Col. C. W. Thomas:—We have listened to an extremely interesting paper and I have no doubt many of you will be anxious to ask questions.

Mr. John P. Leather:—I think it may be interesting, in connection with the earlier portion of the paper, if I state that some eight or ten years ago I was concerned in the designing of a burner suited to the combustion of oil vapour. The oil was vapourised, and the oil vapour was used just as we use gas—through an injector which drew in its own supply of air. It was a successful burner for temperatures of 700-800 degrees C., so that the idea of using oil vapour is not new, although it is quite differently applied in the paper that Mr. Woolf has read to us. I have had no experience, of course, in the burning of oil fuel in tunnel ovens.

Mr. Woolf:—I have referred in my paper to that particular burner, employing induced air. But no matter how the air is brought in, you have still to spray your oil. The method the speaker refers to is an inefficient one, inasmuch as it is in no way comparable to the production of a pure gas. All that you are getting is a condensation—a boiling. It will not by any means split the oil into an absolutely clean gas. You are simply cracking the oil rather than vapourising it.

MR. LEATHER:—No; I claim that it was vapourised.

A MEMBER:—In the laboratory I tackled the same principle that Mr. Woolf has employed and I may say that Mr. Leather's process is identically the same in principle. He has probably not commercialised it, and therefore it has not been known to quite the same extent, but although the details may be slightly different the same result is obtained and the main principle is the same.

MR. WOOLF:—I may say that a firm at Detroit put that same system in. But they wish now that they had not. They cannot get their vapourisers to stand up.

MR. LEATHER:—That may simply be due to the fact that the principle was not properly applied. It is all a question of applying the right principle in the right manner. In your case you may have applied it properly.

DR. E. W. SMITH:—The whole matter seems to be summed up in the fact that Mr. Woolf's system is commercialised in the States, whereas the other is not. On the paper generally, I think Mr. Woolf has to be congratulated in bringing this matter forward. There is no doubt that this method of oil heating is very much better than any direct-fired process. I would point out, though, that it is worth while considering whether rich gas, used with the same amount of intelligence, would not give equally good results. The question also arises: What is the cost of the B.T.U's supplied in the form of oil as compared with the price of the B.T.U's. supplied in the form of gas? Mr. Woolf is paying about 1d. for 8,000. With the same amount of intelligence and appropriateness of design it would be quite possible to get an equal amount of efficiency from gas-firing as from oil fuel; if not, indeed, a greater efficiency. And in such a case you would not encounter the objection of having to put in special apparatus for vapourising the oil. Moreover, you would have an equal degree of control. Now in America the Surface Combustion Co.—a company that handles gas-fired furnaces extensively—has had an extraordinary experience in certain directions, including burning gas efficiently in large furnaces such as Mr. Woolf has been indicating, but other than in tunnel kilns, for over there tunnel kilns are not in very general use. Twelve months ago Dr. Bleininger, a gentleman whom you will all know by repute, could not give any records of satisfactory tunnel kilns that were then working either on gas or oil, other than the Dressler, and there were only one or two instances of that. With big metallurgical furnaces, however, the Surface Combustion Co's process, which was in principle the same as Mr. Woolf's, was giving extraordinarily good results, and an especially high thermal efficiency. The principle included the science of obtaining a proper admixture of air and gas before

combustion took place, and so attaining the maximum temperature in the combustion chamber. This rendered possible the cutting down of the size of the furnace, with a corresponding reduction in radiation losses. Apparently this is exactly what Mr. Woolf's principle claims to do. He is attaining to the maximum temperature within the minimum space, and therefore eliminating losses due to radiation. I do not think there is much more that one can say when approaching a paper of this description quite freshly. It has been an extraordinarily interesting paper, and one that should be taken into very close account by all who are interested in heating. But they will always have to take into account simultaneously the question of the cost of the oil.

MR. WOOLF:— £4 per ton, the present price for oil, is practically equal to 40/- for your coal. But whereas I can get 60-65 per cent. efficiency in my oil furnaces I doubt if there is a single industrial furnace in this country that can give you 50 per cent. efficiency.

DR. SMITH:—I do not think it is fair to compare the best oil practice with the worst coal practice in existence. One ought to compare the best oil practice with the best coal practice. I certainly contend that rich coal firing is actually cheaper than oil firing at the present time, in this country at all events.

MR. WOOLF:—As a matter of fact, this furnace that I have been describing is equally suited to the firing of producer gas, or rich town's gas. We are using city gas to-day on several of our furnaces, but I do not think there is anything going that will beat oil. I hold no brief for oil, I have no oil stock, but I have seen oil used for many years, and I will tell you candidly that I saw only a few days ago in the Midlands a certain firm firing with coke and producing ten articles by means of six men, whereas in little Canada they are doing with oil six times as much with only three men. I can send drop forgings into Sheffield at 4½d. which Sheffield cannot produce for 9d. each. I am not purely and primarily interested in oil. I have another mission. I am intensely patriotic. I have spent from six to eight weeks investigating industrial conditions in England, and I say with conviction that you will have to wake up. We are importing into Canada two million dollars worth of firebrick annually from the U.S.A. Why? Because you are all asleep. I am not choosing my words: I am speaking frankly. Canada needs you, and you will have to come to us. We have got the brains, but you have got the money. We have every rich mineral that you can possibly conceive of in Canada. We have the largest gold mines; we have nickel and coal and we have better labour. But we need your assistance. We want you to come over and we will show you what we have got. That is my mission in England to-day. I came over to see what England can do for Canada, and at the moment I must confess I am disappointed.

MR. MARLOW:—Can the lecturer tell us what weight of pottery ware he is getting with his oven per ton of oil?

MR. WOOLF:—I ought to explain that at the present moment we are not running on oil. The furnace is arranged for oil, but for the time being we are running on towns gas. The furnace is so arranged, however, that without any structural alteration it can be turned over to oil. We are carrying through our preliminary experiments with towns gas. But the same furnace is running to-day all over the country on oil for purposes other than pottery. The pottery which the Lennox firm is producing in Trenton is extremely delicate ware. They are getting for it on the market extraordinarily high prices, in some cases as much as 3,000 dollars for twelve dinner-plates. That being so, they cannot afford to scrap much of it. The fuel cost is a small per cent. as compared with the final selling cost, and as this is the first furnace that we have put down for porcelain the firm has taken the precaution of keeping it on town's gas until the experiments with oil are complete. The results we have already got with oil are good, but we shall get better results yet. We have discovered a number of things in regard to the firing of ceramics that we did not know before. But that we are on the right track is proved by the interest that is being shown in the movement by other pottery people in the States. We have already orders on our books for "Frisco" and Los Angeles. These particular pottery manufacturers had the world to look to for their tunnel kilns, but they came to us. The general interest that is being taken in the movement is proved by the fact that we have about 65 enquiries lying on the table for tunnel kilns costing from 75,000 to 100,000 dollars each. It is an expensive kiln, due to the refractories that we put into it, but that it will pay for itself within a very few years we are positive.

MR. MARLOW:—Do you make the special claim that yours is the only tunnel kiln that will fire glost and biscuit at the same time?

MR. WOOLF:—You cannot do it with a single tunnel kiln.

MR. MARLOW:—I do it every week.

MR. WOOLF:—But I can give you cone 5 or 6 on one side and cone 9 on the other at the same time.

MR. MARLOW:—I could do it just the same with a double kiln.

MR. B. MOORE:—How much fuel would Mr. Woolf suggest must be used in his tunnel kiln to fire a thousand cubic feet of ware?

MR. WOOLF:—The guarantee that we have given the Lennox people is 750 cubic feet, the equivalent of six gallons of oil. We have already a kiln at the Westinghouse Co. running to 800 degs. C., on steel. The last-mentioned can put through about 25 tons of annealed steel per day with an expenditure that is equivalent to

6-8 gallons of oil per hour. That gives you a thermal efficiency for the furnace of about 65 per cent. But the furnace is realy too short for the work. We have built it 50 ft. We wish now that we had built it 60 ft. We built the Lennox pottery kiln 80 ft. long. With our present experience we would have built it 100 ft. long. We are doing the whole output of their plant in 80 ft., or we *shall be doing* when our trials are complete. As I have said, we are still experimenting somewhat with that particular furnace.

MR. CLEVERLEY:—Is this type of kiln being used anywhere for carbonaceous fireclay or such materials as bricks made from pit shale?

MR. WOOLF:—There is no reason in the world why it should not be able to tackle that or any other particular kind of brick. We can give you a muffle furnace; we can give the temperature you require, and we can give you all the excess air that you want, because we can control the air supply at the burner. We can give you an oxidising, a reducing or a neutral flame just as you please. That being so, I cannot see that there would be any difficulty whatever in applying the kiln to whatever particular purposes you may have in view.

DISCUSSION II.

(STOKE MEETING, OCTOBER 17TH, 1921).

MR. J. H. MARLOW:—I would like to ask the lecturer if, at any time, they have used oil fuel at Trenton, New Jersey, in connection with the oven of which he spoke; and if so, did they change over from oil fuel to town's gas?

MR. P. J. WOOLF:—I answered that question, Mr. Marlow, at the meeting in London last week. That particular furnace is sold as an oil furnace, but we are using town's gas with it in order to make our tests. When these tests are completed the furnace will be turned over to oil. Our guarantees are based on oil. You must remember that there are many thousands of dollars' worth of pottery coming through their kilns, and as town's gas was readily obtainable they took it. We are, however, using oil on the Westinghouse kiln. All the kilns that we have sold so far, are for oil burning. It is true that the Trenton, New Jersey kiln is at the present moment using gas. But without any single alteration to the furnace it can be, and will be, changed over to oil. There is nothing else to do but just to cut off the gas valves and open out the oil pipes and it will work.

MR. MARLOW:—That is not my point. I wanted to know if that particular furnace had been tested with oil, and if the samples which you have sent round to us are the result of that oil firing.

MR. WOOLF:—No; the samples now produced have been fired by gas. But the goods will come out just as well with oil.

MR. MARLOW:—I will put my point another way. Will the lecturer tell us whether he has any tunnel oven whatsoever, firing at the present time with oil, that is turning out pottery; and if so, where ?

MR. WOOLF:—Yes, we have; but it is not with this particular kiln, for the reason that it is too modern. We have already adapted four or five kilns for burning oil. But they happen to be 300 ft. long. Our present kiln would be only 150 ft. long to perform the same service. We have three kilns in Newcastle, Pa. using oil. We have one in the same neighbourhood as the Lennox Kiln. This is another make of kiln that is using our gasifying apparatus, that is to say, utilising oil. We have probably in the neighbourhood of six other kilns, working on malleable steel to 2,000° F. all of them using our oil gas vapourisers. The particular furnace at Lennox in which the samples that I have passed round to you were produced is, as I have said, working at the present time with towns' gas, and as a result, it is costing them six or eight times as much as it will when they eventually switch it over to oil. When they turn over to oil they will save many thousands of dollars per annum. I have not a brief to say that the Lennox furnace is absolutely perfect. We are experimenting with it to-day. We have already satisfied ourselves that we have a furnace that is satisfactory in principle. We are quite sure of it, but, like everything that is new, we did not know all that there was to know to start with. We had to make changes which were necessary, principally due to cold spots in the furnace. These were the only structural alterations in the kiln that were necessary. We have modified the furnace with a view to eradicating the cold spots, and we feel that we have succeeded. So clear is it that we have effected a cure that we have already secured orders for five of these furnaces and enquiries for 55 others.

MR. W. EMERY:—Is it natural gas or town's gas that is being used with the Lennox Furnace ?

MR. WOOLF:—Town's Gas.

MR. EMERY:—Have you any data as to the B.T.U. value of the gas ?

MR. WOOLF:—Yes; 400.

MR. EMERY:—And the cubic feet ?

MR. WOOLF:—5,000 cubic ft. per hour. We shall do the same work with from six to eight gallons of oil per hour.

MR. EMERY:—And the cubical capacity of the ware on the trucks ?

MR. WOOLF:—About a thousand cubic feet per day.

DR. J. W. MELLOR:—The point has just been raised whether vaporized oil will do the work at present being done by town's gas. I see no valid reason why the vaporized oil should not do equally well. I would therefore support the lecturer's view that the change from town's gas to oil will give equally satisfactory results when the air and vapour feeds and flues are properly adjusted. I find myself constantly at variance with some of our best gas experts on the best mode of burning gas. For example, I noted that Dr. Smith and Sir Arthur Duckham were very emphatic on the need for rapid combustion, so that the firing chamber could be heated by hot burnt gas. I note too the lecturer favours the same idea.

After a smoke-room discussion on the subject in London, we came to the conclusion, as could have been anticipated, that we are talking about different things. I was referring to a 16-20 ft. oven; they were referring to a relatively small chamber.

Burning the gas rapidly means a high local temperature; this would entail a separate combustion chamber. Provided the firing chambers were small, the *heating is effected by currents of burnt gas*. These currents naturally heat where they hit. Similar results would occur with a large chamber, but here with the vapours in the setting ovens, etc., it would be very difficult to ensure uniformity in the streams of gas. There must be a far greater tendency to short circuitings. In order to help a more uniform distribution of heat, a slower combustion of the burning gas as it works its way through the larger oven appears to be desirable. The distribution of heat is then facilitated by radiation from the flame. The more luminous the flame, the better the radiation. No more heat is given out by rapid combustion than by slow combustion. The effect is well illustrated by the ordinary fish-tail luminous flame and a Bunsen burner, each under a kettle of water, and each burning the same amount of gas. The kettle over the Bunsen burner boils first, because the heat is concentrated on the bottom of the kettle from the Bunsen flame. With the luminous flame however, a marked proportion of the heat is radiated into space. This is evident by holding the hand a few inches from each burner. Similarly with a gas and a coal fire in the room. The radiation of heat from the latter is markedly stronger than from the former. In a large oven, we want to take advantage of this, and make radiation help to equalize the temperature of the oven. I believe that we are on the wrong track if we do not take full advantage of long flame (slow combustion) radiation for heating large ovens.

I had a good bit of experience during the war with oil-spray firing. The results were excellent. Possibly better results would have been obtained by gas-firing with gas obtained by vaporizing oil as advocated by the lecturer. I am afraid I do not appreciate his objection to the use of the term "atomizer" for the elaborated barber's sprayer used with oil firing. The term "atom" has other meanings than that commandeered by the chemist. If I remember rightly, it is the original term for a moment of time, translated in the New Testament by twinkling of an eye.

The price we have to pay for excess air in pottery ovens is a serious one; and while I agree wholly with what he says about boiler firing, we must have with the present system of firing bone china biscuit over 50 per cent. excess air. I have emphasized this so often, and it is indicated in so many papers in the Transactions that there is no need to say more at the present time.

I must express my admiration of the ingenuity of the counter-current tunnel system of utilizing spent heat. It is quite new to me. I hope that it passes successfully through the fiery ordeal by which all ingenious ideas must be remorselessly tested, before they can win a place in commercial practice.

MR. WOOLF:—I have a letter here written to my firm by a Company in Chicago, in which they state that by using our vaporisers they have increased their output from 75 lbs. per gallon of oil to 375 lbs. per gallon. A large electrical firm reduced their consumption in annealing sheets in a tunnel kiln from 47 gallons of oil per ton of handled material to under 6 gallons. Further, we have succeeded in getting down the time for malleable treatments from eight days to five. The question of attendance is also very important. In a brickworks it has been found that one attendant is capable of attending to six furnaces.

MR. C. BAILEY:—We have been fortunate enough to listen to a very interesting paper and to have seen slides of a kiln which is certainly of a very original character. The lines upon which the kiln has been developed are just the lines that the pottery manufacturers have been anxiously waiting for, that is to say, a kiln offering something like a decent output, occupying a reasonable ground space, and a kiln that will utilise as far as possible the waste heat gases. It is an original proposition and an interesting one. It is, however, one that is difficult to grasp completely and to criticise effectively in a first evening. If we had been fortunate enough to have had the paper distributed earlier, and to have had an opportunity of examining it before the meeting, we would possibly have been able to put up a more intelligent criticism. I would like to ask Mr. Woolf how far the flexibility of his kiln is able to go.

MR. WOOLF:—The Westinghouse Co. is working up to 1,300 degs. F., or 800 degs. C. The Lennox Kiln is working up to 2,200 degs. F. or 1,300 degs. C.

MR. J. W. MEREDITH:—What is the heating curve of the kiln ?

MR. WOOLF:—It is practically a straight line on the Lennox kiln. Assuming that we take 10 hours to heat, the goods would be from 2-3 hours in the combustion zone. We get practically a straight line from the first hour. It is a very special curve during the first hour. We get up to about 300 degs. in the first hour or an hour and a half, and then from 300 to 1,300 degs. it is practically a straight line. There is a variation at the top and bottom of the kiln starting at 150 degs., gradually reducing to a temperature of equalisation by the time the ware reaches the combustion zone. I will see that Dr. Mellor gets these curves before many weeks have passed. The curve of which I am speaking was taken on the first trial run that we ever put through the Lennox kiln.

MR. MARLOW:—The lecturer mentions that only one man is necessary to operate his kiln. Does he mean one man to operate the oil burners ?

MR. WOOLF:—What I mean is that there is not necessarily a man for operating. There is a superintendent assisted by a couple of loaders. The superintendent looks after the firing of the kiln.

MR. MARLOW:—That is just what we have under the old system.

MR. WOOLF:—I claim that there is a saving of labour in this proposition. For instance, it will take about three men per shift to get out 1,000 cubic feet or more per day.

MR. MARLOW:—Does that include the placing ?

MR. WOOLF:—Yes.

MR. MARLOW:—You are of the opinion that one fireman retained on firing alone could operate half a dozen kilns ?

MR. WOOLF:—Yes. That is what we are aiming at, to get a therm regulation. We are getting out a thermo-couple connected with relays which will operate directly on the valve and determine the flow of oil to the furnace.

MR. MARLOW:—Can the lecturer tell us of any particular oven which rises to 300 degs. in an hour or an hour and a half and afterwards rises in temperature regularly all the way, and produces ware that is perfect ?

MR. WOOLF:—I answered that, Mr. Marlow. My reply is the Lennox furnace, although I am not claiming that our first effort with the Lennox kiln was perfect.

MR. MARLOW:—I am asking the lecturer if he can give us any information with regard to an oven of the size stated in which the ware has been raised to a temperature of 300 degs. in an hour and a half, and then raised to any temperature he likes to mention, where the ware has been perfect ?

MR. WOOLF:—The Lennox kiln is 80 ft. long, and generally we aim to get out one car every hour. There are roughly 13 cars on a side.

MR. MARLOW:—I do not like to dispute the statement made by the lecturer, but I will guarantee that there is not a tile manufacturer who could put tiles into an oven which rises in temperature during the first hour and a half to 300 degs., and produce 5 per cent. of satisfactory goods at the other end.

MR. WOOLF:—You have to realise that this ware at Lennox has all the moisture taken out of it first.

MR. MARLOW:—In that case the length of your tunnel kiln is double.

MR. WOOLF:—No, the drying is done in a continuous drying furnace with which we have nothing at all to do. We do not attempt to dry the goods in this furnace.

MR. MARLOW:—At what temperature does the ware leave the drying furnace ?

MR. WOOLF:—I do not know. The ware comes to the kiln at atmospheric temperature.

MR. MARLOW:—Does the ware go in hot or cold ?

MR. WOOLF:—Cold.

MR. MARLOW:—Well, the effect on that ware would be the same as I have stated. If you put the ware in cold you can fire it to whatever temperature you like and you will not get 5 per cent. of good flooring tiles coming through at the other end.

MR. WOOLF:—Your point is well taken, Mr. Marlow. But, as I have stated before, in the case of the Lennox furnace, we were limited in space to 80 ft. If I were to build that kiln again, I would build it 100 ft., and instead of getting that steep rising curve we should get a more gradual one.

MR. MARLOW:—I must again differ from the lecturer, because he says that at Lennox they are getting perfect ware. If that is

the case why lengthen the kiln ? I, for one, would take one of these kilns if Mr. Woolf can prove to me that he can get our ware perfect in 100 ft. of ground space.

MR. WOOLF:—I will take your offer, Mr. Marlow.

MR. C. BAILEY:—It seems to me that what is suitable for a factory making such goods as have been handed round to us—hollow-ware pieces—would not necessarily be suitable for a flooring tile manufacturer. If I were Mr. Woolf, I would be inclined to hesitate before accepting Mr. Marlow's offer. At the same time, Mr. Marlow is only putting forward the position as it affects a limited section of the Ceramic industry. Although I myself would hesitate before building a kiln of only 100 ft. in length, or anything like it, rising to 300 degs. in an hour and a half, for a tile manufacturer, I would not have the same hesitation in building a short kiln for such articles as cups, or teapots or jugs.

MR. WOOLF:—I think Mr. Marlow does not appreciate the point that we have in that 100 ft. furnace the equivalent of 200 ft. of length. A truck comes *from each side* every two hours. I explained that the Lennox furnace is a success with cups and saucers and similar articles, but it might not be equally a success where one has to deal with thick masses of tile; it would have to be longer. If, however, you sent the ware through dry, *i.e.*, with not more than one or two per cent. of moisture, then I think the furnace would be a success. We are to-day putting it on to water closets and large articles of that kind. These articles have thicknesses of material very nearly twice or three times what you have to deal with in the tile trade, and incidentally the goods are coming through without saggars, in other words, with car furniture, just the same as your kiln is coming through without saggars for tiles.

MR. MARLOW:—I am afraid you are wrong there. I use saggars.

MR. WOOLF:—Well, I claim then, that within 20 years you will not use a saggar, although I would like to clear the pitch by saying that I am not trying to sell a kiln that will fire without saggars. I am not by any means a pottery expert; I am only an accident.

MR. J. WILLIAMSON:—What is the capacity of the kiln ?

MR. WOOLF:—The one described on the slide is roughly 650 cubic ft. to 1,000 ft.

MR. WILLIAMSON:—Also, what is the difference of temperature between the goods on the combustion side of the oven and on the wall side.

MR. WOOLF:—I cannot say exactly.

MR. WILLIAMSON:—Is there any difference ?

MR. WOOLF:—I explained to you that in the Lennox kiln we get a cold spot, but otherwise there was an equalised temperature.

MR. WILLIAMSON:—What is the difference between the top and the bottom of the kiln ?

MR. WOOLF:—I should say a difference varying between cones 7-9.

MR. WILLIAMSON:—Can you give us any idea as to the quantity or weight of goods produced from a gallon of oil ?

MR. WOOLF:—About eight gallons of oil per hour would be utilised in a kiln such as I have described.

MR. WILLIAMSON:—Supposing you take a truck of two cubic metres per hour, what can you fire that for ?

MR. WOOLF:—That would be about seventy cubic feet per car. I should do that with about sixteen gallons of oil per hour, *i.e.*, about eight gallons of oil to the cubic metre. This is a mental calculation, but I think it is about correct. In regard to costs, you have to bear in mind that the oil that you are buying to-day has gone through four or five processes before you get it. It is first of all cracked to 200 degs., when off comes the gasolene. Then to another 200 degs., when off comes the kerosene. Lastly comes off the lubricating oil, and you have left a distillate which it does not pay the oil companies to crack further, because there is no market for it. Oil is sold in different forms, some as crude oil, some as fuel oil. The former is a thick, tarry mass, but you need not be worried about the appearance of it. So long as you can make the oil flow, that particular method of ours will vaporise it, because oil will completely vaporise at 400 degrees C. There is a certain percentage of carbon left behind, but this difficulty we have surmounted. I have not discussed that in my paper. We got into difficulties at first owing to the carbonization which took place inside the manifolds, but we managed to overcome it entirely. By our method we secure a natural gas, but it is superheated. I have myself seen an open-hearth furnace firing at 1,350 degrees F., checked by a radiation pyrometer. Now that is almost the theoretical temperature that you can get with complete combustion of the carbon. I have seen the same furnace working at 500 degrees F., in other words, the furnace is extraordinarily flexible. I could adapt it without much trouble to do your drying. We are, as a matter of fact, drying cores to-day throughout the United States—numbers of them—in foundries, using oil.

With regard to Mr. Marlow's point about saggars, that is a matter that you potters know more about than I do, but I claim

that before very long you won't see saggars—or rather a complete saggar. You may, if you wish, use saggars—the Lennox firm are using saggars,—but we have put the ware through without saggars.

MR. WILLIAMSON:—It would have been more interesting if the lecturer could have given us more details of the arrangment for vaporizing the oil as I believe there is a good deal to be said regarding this method of burning oil over the usual method of spraying.

MR. WOOLF:—I am sorry that I cannot give you further details to-night, as I have left the slides in London, but will let Dr. Mellor have further particulars of the arrangement.

MR. WILLIAMSON:—Do I understand that you have already ovens working for the open annealing of sheet steel without boxes ?

MR. WOOLF:—Yes, in America we have an oven annealing sheet steel and wire without boxes, but not for bright steel.

THE CHAIRMAN:—Has it been done satisfactorily ?

MR. WOOLF:—Absolutely. I do not say that it was not an accident. I should have to run the furnace for six months before I could tell you definitely whether we could do it commercially.

MR. W. EMERY:—The lecturer has made a statement that the radiation losses are only half of any other tunnel kiln. I suppose this does not include the Zwermann kiln, of the twin tunnel type ?

MR. WOOLF:—My remark is not intended to include that particular kiln, which is on the same principle as ours, but does not embrace the principles of radiation and convection. What I intended to refer to was any tunnel oven of the single chamber type.

MR. CUTHBERT BAILEY:—As we are rather limited for time, Dr. Mellor suggests that, seeing that this problem is one which will need a little pondering over, any further questions might be submitted in writing, when they will be forwarded to Mr. Woolf, and inserted, along with the remainder of the discussion, in the printed "TRANSACTIONS."

MAJOR B. J. MOORE:—I have to propose a hearty vote of thanks to Mr. Woolf for his kindness in coming here to-day. I am sure Mr. Woolf's remarks have given us very great food for thought. Perhaps the first thing that struck me was the fact that it will be necessary for us all, if we are considering the adoption of any type of gaseous fuel burning, to consider seriously this question of fuel oil, because I am sure we are all agreed, for we must all realise, that it offers a cleaner and a more facile method of working. What is more important, it enables us to arrive at some form or standard which is difficult when using other types

of fuel. I know myself, from the slight interest that I have taken in gas furnaces, that considerable trouble is encountered owing to the great variations that one experiences in the fuels that are fed into the producer. But perhaps most of all, the point that strikes those who are engaged in the pottery trade is the fact that, if we follow up what Mr. Woolf says in regard to the twin tunnel, the furnace should occupy very much less room than a furnace devised for the same output with a single tunnel. And if the claims that Mr. Woolf submits for his kiln are right, it will certainly meet with our approval because of the fact that our factories, generally speaking, are very congested. The kiln seems to offer many novel attractions, and if it will do all that is claimed for it—and all that we hope it will—I think it will go a good way towards solving our present firing difficulties.

Mr. F. Turner:—It gives me much pleasure to second the vote of thanks to the lecturer. I would have liked to have asked him a host of questions about the kiln, but it is quite impossible at this late hour. Certainly, I am very much interested in the possibilities that surround the utilization of oil as a fuel, providing that it is sufficiently economical. In the Potteries, naturally, the first thought is economy. Oil, the lecturer says, is now selling at £4 per ton. But supposing the whole of the potters were to put down oil kilns, what is the price of oil likely to be then ? I remember some experiments that were carried out in connection with oil firing some years ago. The results obtained were perfectly satisfactory from a firing point of view, but the price of oil jumped up to such an extent that it was ruled right out of the question. Certainly oil would offer a very clean fuel medium. As far as the kiln itself is concerned, I am afraid I cannot offer any remarks that will bear upon it seriously. The ideal kiln, undoubtedly, from the potters' point of view would be a continuous kiln which occupies very little ground space. Unfortunately, any such type of kiln has always had some very serious disadvantages. The lecturer himself mentioned one—the Lennox kiln, in connection with which the initial temperature is very high. Possibly, lengthening the kiln by some twenty feet might correct that somewhat. I do not know. But other kilns have had that same disadvantage, although they have been very much longer. Still, a kiln of this type, or any other continuous kiln which can be built into a small space, would undoubtedly be of tremendous value to the pottery industry. The kiln is worthy of the serious consideration of all of us, in order that we may investigate whether we have at last arrived at the perfect kiln. Amongst the number of different types of kilns that one is hearing about just now, one is apt to get a little bewildered. However, it is possible that perfection may emerge out of chaos in due time.

XIII.—Symposium on Gas Firing. II.

Lt.-Col. C. W. Thomas:—In re-opening our symposium on gas-firing it will, I think, probably be most useful if we carry on into that discussion whatever was left unsaid this morning about oil-firing. Those of you who were present at the Stoke-on-Trent meeting will remember the line which was taken in the first portion of our deliberations, which were reported at length in the "*Transactions.*" I think in many ways it was by far the most interesting discussion that we have had for some time in the Refractory Materials Section, and its importance to the industry as a whole must be admitted. There are a great many factors to consider in dealing with this question. There is not only the question of economy in fuel; there is also the question of possible economies in labour; and another point that has to be taken rather seriously into account is the question of the capital charges that are called into being by the respective processes. I think it is admitted that the wear and tear by gas-firing, under favourable conditions, is less than we get by coal-firing—by that, of course, I mean direct firing. On the other hand, there are some conditions which may very readily give us a very much more rapid wear and tear locally in a gas-fired furnace. I do not say that this would be the case in a properly adjusted gas-fired furnace, but one knows that the precision of the laboratory is a very different thing from what one sometimes achieves in a works.

In discussing this question we have to bear in mind specially the requirements of individual branches of the refractory materials industry in the shape of heat application. In moving about from one works to another, one cannot help being struck by the fact that the conditions are not always the same, either from the aspect of the plant or the conditions under which the respective wares are produced. Furthermore, the materials requiring the application of any form of heating are always more or less variable. In extension of the same idea it may be pointed out that in one works you will find a predominence of a particular class of ware, whilst in another works you will find that a totally different class of ware constitutes more than half the output. Now you cannot, of course, treat all classes of ware in the same way, and therefore a type of kiln, or a method of firing, that would suit one works, might have to be seriously modified before it would suit another. These are only some of the points that we have to bear in mind in discussing the general problems, but they are points which make it rather difficult for the average man, interested in the commercial side of the problem, to commit himself to a definite opinion as to which precisely is the best type

of kiln or method of firing for him, personally, to adopt. We have here with us to-day Sir Arthur Duckham, who has been largely interested both in the question of fuel conservation and the application of gas to industrial heating. I think it would be very interesting if we could now have his views on the subject generally.

Sir Arthur Duckham:—Some little time ago, when Dr. Mellor mentioned that this question was going to be renewed at your meeting to-day, we were talking the matter over together, and I said I would be very glad to express before the Society any ideas that I might have on the subject. Unfortunately, I have been incapacitated for about eight weeks. I returned to town only on Monday. I had to take the chair at a meeting yesterday, and spoke altogether about five times, so that I have not been able to prepare anything worthy of you to-day. If, however, at any time I can make any further communication on the subject, I shall be delighted to do so.

To open a symposium on a subject does not seem to be quite so terrible a thing as to give an address upon it. At all events, the word "symposium" appears to me somewhat of an opacifying nature.

I have always looked at the question of the application of gas-firing to kilns in this way. Supposing that you are a manufacturer, doing pretty well, making a certain amount of money, and having on the whole a fairly quiet and happy time. My friend at the next works is a go-head fellow, who has seen the new-fangled gas-fired kilns and put them in. But he is getting his troubles; his ware does not come out just as he would like; and he is getting to bed late o' nights as a consequence. Should I not be apt to ask: "Am I not having a happier life than he?" That, I am sure, is a feeling that is very prevalent among the manufacturers of ceramic wares to-day. And it is a very natural attitude to take up, because, after all, of the work that is done in connection with ceramics quite a large proportion is dependent upon the human element, and in the ordinary direct-firing by coal you have the advantage of generations of people who are born kiln firemen, and who know just to a nicety how to fire a kiln by that means. They may not know just *why* they do a thing in a particular way, but they know just *how* to do it in order to get the best results. When you come to switch these men over to the question of gaseous firing, which is an entirely different proposition, you cannot hope, unless you have really good supervision, to get the results you want.

In passing, I may say that I have built, or I should say my firm have built, hundreds of installations designed for gaseous firing, and it is a fact that you may have half a dozen works, built exactly the same, every brick and every flue the same, and whilst you may have three or four which work absolutely splendidly, with perfect regulation of heat, at the other works, through lack

of understanding or attention, you will have the plant working badly. Now the position to-day is this: the man with the direct-fired kiln is told that he is a disgrace to the nation, because he is wasting fuel, and that that is a shameful thing to do when one remembers that fuel is the life-blood of the country. You can imagine that man looking at his kiln and saying "Where am I wasting fuel ? " He sees smoke belching out at the top of his chimney when the fireman is putting another charge in the fire-holes, and it possibly occurs to him that he can save that waste by conducting the waste heat to some form of regeneration or a waste heat boiler. He sets to work and does that, and he then probably says to himself "Now I am getting practically the whole of the heat out of my kiln." Well, he is; except that he has not taken into account the question of the radiation of the heat from his kiln. And usually—although not always—in the old-fashioned direct-fired kiln you are apt to get more radiation than with a set of up-to-date gaseous-fired kilns grouped together in a scientific way.

There is another point, and that is, that with direct-firing you are apt to get localised heating. I am not speaking now of the "smoking" period, because when you are "smoking" you are not getting complete combustion; you are simply passing hot gases through the kiln. But with direct-firing you do get a very keen localised heating, because you are burning the gases at an extremely high flame temperature. It is very difficult by means of localised fire-holes to spread your heat through the kiln. This seems to me to be one of the first things that you might put to the man with a direct-fired kiln, and who said he was satisfied with it. You might point out to him that the bungs of his ware on the outside of his kiln are hotter than the bungs on the inside. You might say to him: "Would it not be very much better if you were to take that heat and apply it so that you could regulate it to the best advantage ? "

Having convinced the owner of the direct-fired kiln that he would be able to get a very direct economy by utilising gas instead of solid fuel, he might go to a contractor—whom he expects to know all about these things—and ask him to build him a gas-fired kiln. But despite the best attention that is given to him by his contractor and the men who are engaged by him, who all of them know something about the job in hand, he eventually gets into trouble. Possibly he may forget that he has now to make gas in his producer, and instead of doing that, he may proceed to work his producer as an open fire, running the products of combustion in the same way as in an ordinary kiln. He will find that he gets clinker troubles. Then someone might suggest to him that he must put more steam under his fire bars in order to reduce the clinker troubles. But when he has done that he will probably find that he cannot get his heat, because the question of vapour

in a producer gas is a very important point.

Bearing in mind all these points, one really cannot blame people having direct-fired furnaces for thinking a good many times before they go in for gas-firing. I think it is very essential that we should all realise first of all the necessities of gaseous firing. To get the advantage of gaseous firing you must first of all have a producer for a number of kilns, otherwise you may have to let that producer up and down just as you have to do with the direct-fire holes of an ordinary kiln. Another very essential point to remember is that you have to get your producer gas as hot as possible into the kiln, because loss of sensible heat in the producer gas is, of course, a loss that is absolutely direct, and for which there is no excuse. Then, perhaps, the most important question that has to be faced is: How are you going to burn your gases in the kiln ? Are you going to heat your goods by an absolutely direct flame on to your goods or on your ware? Are you going to try to get your oven heated by elongating the flame from your producer gas, or are you going to do it by means of a combustion chamber, and conducting the hot products of combustion over the goods that you wish to burn ? From my experience of normal work I rather disagree with the views that were expressed by Mr. Dunnachie, at the Stoke meeting. My opinion is that you should endeavour to get your combustion perfected in a chamber from which radiation is prevented, and from which the very hot products are carried rather evenly over your ware, because where you are working a kiln in which you want your heat all through to be the same, it is very difficult, to my mind, to work a flame—especially with the attentions given by the ordinary fireman—in such a way that it goes right through your ware, and heats it up evenly, *i.e.*, without excessive heating on exposed places.

Another question that enters in relation to pottery kilns and in other kilns that have to be taken good care of with producer gas-firing, is the question of the "smoking" or first heating of the kiln in which the wares are placed. This with a producer gas-fired kiln is always somewhat of a difficulty. It can be arranged for where you have a series of kilns or a series of chambers working one after the other. But you can understand the risk of gases coming forward charged with water vapour, through the moisture coming off your goods, and the consequent danger of sulphur being present. I think a condition of gaseous firing will be the pre-drying of the kilns—the raising of the temperature by hot air, either air heated by recuperation or some other form of waste heat, so that you will have the goods dried off before you go seriously ahead with the firing proper.

Then again, there is the question of recuperation. There is no doubt about it that to get satisfactory results you should have hot secondary air. In many kilns, trouble occurs owing to the

producer gas being cold and the secondary air not being sufficiently heated. With hot secondary air and hot producer gas, brought into a suitable chamber and the outlets so arranged that the two can percolate through holes into the kiln, I am certain that you will get satisfactory working. There is not the slightest doubt about it, however, that you will have to train your men to the work. It is no good putting in tunnel ovens unless you are sure that the men are specially trained to the job, and you must not expect to get the same excellent attention from the man who has been born and reared under the older conditions of pottery firing and who can trace back his firing progenitors right away to the time of the Pharoahs. I am certain that a great deal of the trouble that is experienced with gas-firing is due to the non-recognition of this important fact.

Dr. E. W. Smith:—Seeing that I opened the discussion last year, I thought I was going to be spared the necessity of having to take part in the discussion to-day, and particularly as my chief, Sir Arthur Duckham, had promised to reopen the discussion. Anything that I may have to say now will only take the form of a few notes upon the subject of gas-firing, and probably carry on, to some extent, the discussion which took place this morning on oil firing.

We were accused this morning of being asleep in this country, but the bitter pill was sugared to some extent by the statement that we had brains and money. Well, if the first point is as accurate as the last, we need not take much notice of it. We certainly have not money, and the chief reason of our not being better off, as regards gaseous-firing or oil-firing in this country, is not that we have not the intelligence or that we are asleep, but very largely that we have not the money; the capital expenditure cannot be found for these kilns in England, any more than it can be found in Canada. We are only just starting, I think, along these lines. I think we are just as patriotic in our own little way as the Canadians are. I could not gather quite what it was that the speaker wanted to get at. Apparently the chief incentive was that we should have a greater output. If that is so, we agree with Mr. Woolf entirely that it should be possible with oil-firing or gaseous-firing to get better products and a greater output than with direct firing. Mr. Woolf's panacea, however, was the use of oil, and by inference I gather that this was going to be a patriotic thing to do. Well, I wonder just how much oil we could supply in this country if we were to use our own fuel, and not have to go to any other country. Would our dominion resources, even, be sufficient to keep pace with our requirements? We are convinced of the advantages of using oil over coal in direct fires, but we are still in the position that, having got coal and no oil, if we are to embark upon fresh methods of firing, the only product

that we can use in a scientific way is gas, whether that be producer gas or coal gas. It is all a matter of economics. Even if we were patriotic enough to use oil, or if Canada and her sister countries could produce quite sufficient for our use, we have still to face the fact that we have coal at our doors, and that we can get gas from that coal either as producer gas or as coal gas. Do not, however, let me give you the impression that for one moment I am attempting to depreciate the extraordinary value of the principles that underlie the whole of Mr. Woolf's paper. In the elementals of his paper I am in perfect agreement with him.

In considering the question of gas-firing, it has been appreciated for some time that you have first of all to decide on the type of gas that you are going to use. When you have decided upon the type of gas—and it is usually a question of cost which determines your choice—you have next to decide how you are going to apply it, because gas alone will not do the trick. It is just here that the whole of what was said this morning as regards oil can be brought into effect. In all cases the best results will be obtained when you get quick perfect combustion. Instead of delaying the combustion as with a long flame, and letting the air gradually mix with the combustible gas, you must make such arrangements that the whole of the gas as it exudes into the combustion chamber shall be combusted, almost instantaneously. This can only be done by bringing about a sufficient mixture of air and gas prior to combustion. Now this is not so easy a thing as it appears at first sight. When handling coal gas, which is clean and cold—because it is never the custom to regenerate coal gas except in such instances as cokeovens where the bye-product gas is used and where the air passes through the recuperater and burns up the carbon that has been deposited in the process of recuperation—the coal gas can be mixed with air, very efficiently, prior to combustion. With cold producer gas you could bring about similar results, but no one would ever propose to use cold producer gas for this purpose. The only efficient way of using producer gas is to use it hot, and, therefore, special arrangements have to be made in order to bring about an intimate admixture after the escape of the air and the gas. This can be done, and is done, in a properly designed combustion chamber.

Little has been said of the use of city gas or town's gas for large industrial work; not because it is not within the realm of practical politics, but because it is not so general in its application. I mentioned this morning that in the States there are very big furnaces—bigger in some instances than the largest tunnel kilns—which are being heated by means of gas—city gas, as they call it—in a very big and very general way. From the point of view of cost this is being done cheaper in many instances than if the furnaces were heated by means of oil, even at its relatively much lower price in the States than city gas. It depends entirely upon

the particular proposition with which one has to deal. In spite of the fact that relatively the price of gas in the States is much cheaper than the price of oil, there are instances over there as there will also be instances in this country, where it will pay to use city gas or towns' gas. If it pays to use oil, when oil stands as it does to-day in this country at about £4 per ton, it will certainly pay to use town's gas. But I do not propose to apply myself particularly to this aspect of the question to-day.

With producer gas there are very many dangers, as Sir Arthur Duckham has suggested. Producer gas has to be used very intelligently. There is first of all the question of the producer. The particular fuel that is used in the producer is also a live factor in connection with its working. If the producer ash is a bad one—if it clinkers easily—then steam has to be used; some of this steam is converted into hydrogen, but the main bulk of it passes into the gas and goes through as water vapour. This water vapour is not only there as a diluent but as a serious diluent. The amount of heat that it will absorb as compared with any of the other gases is just about twice as much per unit. This makes a considerable difference in the flame temperature that is attained, and flame temperature is the crucial point in efficient heating. Delayed combustion means low flame temperature; intensive combustion means high flame temperature.

Again, in actual work you must provide for radiant heating. Sir Arthur Duckham pointed out that it is advisable, indeed almost necessary, to heat by means of waste gases which are at their maximum temperature. Now maximum temperature cannot be attained unless you are running under proper and efficient conditions. And these conditions are varied. Recently in certain Government departments there has been an enquiry into the question of inerts in city gas, and particularly into the question of carbon monoxide in city gas. It was illuminating in regard to the latter point that it was stated to be a big advantage in all heating propositions to encourage the percentage of carbon monoxide, for the reason that, as a gas, it has a higher radiating value, and consequently the effective heating of the combustion chamber is rendered much greater thereby. Now, in producer gas-firing you are using, under non-recovery conditions, a higher percentage of carbon monoxide compared with other combustible gases. The Government department in question further specified that there should be no restrictions in the percentage of inert gases in the saleable gas of commerce, subject to the gas being sold entirely on a therm basis. Within fairly broad limits I think it is a fact that one can expect that varying percentages of inerts can be ignored, subject to the inerts being constant in any given area.

The only other point that I would like to bring to your notice before resuming my seat is in reference to a new method of gaseous-

firing. In the States they have developed to some extent—and it appears to me to offer fairly good prospects—a system known as the Daytoh oil gas. I have seen a plant working with this oil gas, and have inspected the operations that it is performing. In one case the plant has been working from 9 to 12 months, and they have been getting with it very satisfactory results. I mention this matter not with the view of advocating the use of this particular gas in our own country, but more as a matter of technical interest in connection with a new method of making gas. The gas in question may be termed an oil producer gas, in the respect that you take oil, preheat it, and pass it into a small cast iron chamber. To start up, the cast iron chamber is preheated, and along with the oil is injected a small quantity of air. In this chamber the oil particularly combusts with the small quantity of air admitted, and supplies sufficient heat for the continued cracking of the rest of the oil. After the first starting up there is enough internal heat for the continued cracking of the rest of the oil in the chamber. From the outlet of the chamber is obtained a quantity of gas and a little tar. The gas has a cal. value of approximately 450 B.T.U. About 4 gallons of oil are used per thousand cubic feet of gas. The gas is a rather extraordinary one from the aspect that it contains a rather large proportion of ethylene. But the temperatures that are attained with it in commercial practice at the Pierce Arrow Works, at Detroit, are said to be all that are required. With this particular gas you can employ methods of regeneration, recuperation, preheating of the air, and so on, in order to bring up the temperature to anything that you require. It appears to me to be a somewhat novel method of producing gas, and seeing that in many industrial concerns it would no doubt pay undertakings to put in their own gas plant rather than pay for the distribution costs of the rest of the community, it is possible that in some instances this particular process might be considered an advantage, especially as it would be self-contained, and would cover a comparatively small groundspace.

Mr. H. M. Ridge:—The question of fuel economy looms very large once more. I want to say "once more," because it is not an eminently new subject for discussion, but symposiums on the subject are comparatively new. The question of fuel economy has been considered by many people over long periods of years. To give just a short idea of how fuel economy has been effected during recent decades, I will mention one case. Fifty years ago, for a certain furnace capacity, the consumption of coal was 450 tons. Siemens regenerators were installed, and the coal consumption dropped, to start with, to 250 tons. I am speaking always of the same furnace output. Further improvements were made in the furnace, particularly as regards the travel of the gas and the details of the regenerators, and the coal was brought down

again to 125 tons. This having been accomplished, the census of opinion was that finality had been reached, but it had not. It is true that in this particular instance the further improvement on that 125 tons of coal was slow process, and it took about 20 years to bring the consumption down to between 100 and 110 tons. But even that was not finality. A marked improvement was suddenly made by me to 80 tons and, as a result of experience, I have recently been able to bring it as low as 65 tons. I think that these last-mentioned economies are rather remarkable, seeing that they have been effected entirely since the year 1914.

Fifteen or twenty years ago fuel economy was not considered to be of extreme importance in Great Britain. This was due, no doubt, to the low price of coal and the ease with which it was obtained. During the war, however, the conditions altered. For a time, we were short of coal, and apart from that, the price rose tremendously. Now, in the ceramic and metallurgical industries, competition from abroad is an important item, and at the present time we have, I think, to look mainly towards competition from Germany. On the occasion of the visit of our Society in May last to Alsace-Lorraine, I made use of the opportunity to enquire what was the price of coal as used by the Germans in their works. I found that it was at that time about 270 marks, and taking into account the rate of exchange as it stood then, this was equal to about £1 per ton— a figure that we hardly dare hope to reach in this country at the present time. Being faced with higher prices of coal than our foreign competitors, we are forced to consider the possibility of making our coal go farther. In continuous kilns of various types good results have already been attained in this direction; the fuel consumption has been considerably reduced. But at the present time the cost of reconstructing and altering works is so high that manufacturers in many cases cannot possibly face the necessary expenditure. It seems to me that modification, alteration or improvement of the existing kilns should, therefore, be closely considered, with a view to an improvement being effected at the lowest possible outlay.

In the preliminary portion of the discussion at Stoke in April of last year, Mr. E. M. Myers remarked: "The importance of the correct application of heat treatment in every industry is almost beyond comprehension." I agree. Mr. Myers further said: "Throughout the whole of the industry the question of the correct application of heat and the consumption fo fuel lies at the very root of the cost of production." Again I agree, and if that argument applied last year it applies with even greater force this year. If coal is to be saved and the cost of production reduced, the heating arrangements, under present conditions, have got to comply very fully with a few very essential requirements. Amongst these I should put: (1) Greater possible independence of skilled labour; (2) any apparatus put into use must be easily and readily

adjusted to the requirements and conditions within the kilns; and (3) there must be an absolute minimum of unburnt carbon.

Taking gas analyses, in spite of an excess of oxygen in the waste gases, I have found as much as up to one per cent. of CO notwithstanding 50 per cent. excess of air. In the case of fine pottery, I know that there must be a certain amount of excess air in order to prevent discolouration of the ware, but in the case of the firebrick manufacturer, excess air should be avoided, because it entails such a considerable loss of heat in the waste gases. To comply with these requirements the firing arrangements should be such that the volatile hydrocarbons from the coal are subjected in the first place to a temperature sufficiently high to decompose them. That is apparently a bold statement to make, but it can be done. As the result of some rather prolonged investigations I have found not only that we can do it, but that by utilising means for ensuring the decomposition of the hydrocarbons before the admission of sufficient air to burn the CO, you can materially reduce your fuel consumption. I discovered abroad an apparatus in use at a particular works, and made arrangements for its installation over here. It is an apparatus that has certain limitations It has been used up to now in numerous cases for replacing the ordinary firegrates, but only where the amounts of coal to be burned per 24 hours are limited to a maximum of between 30-40 cwts. per grate. The apparatus in question is really a glorified firegrate, simple but effective. I have found, both during and since the war, that we are able to utilise it with unskilled labour. By simply putting it in where an ordinary firegrate had previously been used, and without making any further alterations, we have been able to reduce the coal consumption by about 40 per cent.—not a bad figure when one reflects that the whole apparatus costs very little. It gives one further advantage, viz.:—a free, continuous and regular supply of gas. Without any alteration to dampers, I have found only a variation of about one per cent. in the CO_2 content of the gas except of course, during actual stoking.

To turn to another point: in the spring of last year, Mr. Dunnachie spoke of the danger of gas kilns being too elaborate and complicated in the direction of flues and dampers. He said the most satisfactory kiln was the one which would give uniform burning combined with the maximum simplicity. I think this is essential. It is no use trying to put in some highly complicated apparatus. Some of the previous speakers have already referred to the complications caused by installing gas producers in existing works. In my opinion, a further appreciable economy in fuel consumption is possible in many works by the utilisation of the waste gases from the kilns for preheating the air required in the burning of fresh goods. This was spoken of to some extent at the spring meeting last year.

I would like, if it will not weary you, to give a few figures, based

on the analysis of the coal supplied to a kiln showing 75 per cent C, 5 per cent. H_2, 3 per cent. H_2O and 17 per cent. ash. The ash, as will be seen, is rather high, but I think we have all been experiencing this lately; in fact, I have found it to be as high as 24 per cent. If the coal is burned and the gases are allowed to leave the furnace and go up the stack at a temperature of 800 degrees C., which is not an unusually high temperature in general practice, and using as required on the pottery side 50 per cent. excess of air, we get a CO_2 content in the gas of about 12 per cent., and 46·1 per cent. of the total heat which can be got from the coal is lost in the stack gases. If, however, we bring down the temperature of the stack gases to 600 degs. C., although the loss of heat is reduced, it is still as high as 33·9 per cent.—a pretty big figure. By reducing the waste gas temperature to 300°C., the loss is reduced to 15·8 per cent.

I would like to give you a few figures also as applicable to gases where excess of air is not required in burning. With no excess air you would get theoretically 18·1 per cent. CO_2, but in practice you never actually reach that. I have found that I can comfortably get 16·7 to 17·6 per cent. On taking the maximum theoretical figure of 18·1 per cent, I find that with a waste gas temperature of 800°C. the loss is 32·2 per cent., whereas, if you work under the rather more favourable conditions, *i.e.*, a waste gas temperature of 600°C., the loss will be only 23·6 per cent., and with 300°C. only 11·0 per cent., I have found that this last result can be attained in works practice and have already succeeded in improving upon it.

I think that these figures give us a certain amount of food for thought. What are the lessons to be drawn from them ? One of the previous speakers to-day has mentioned the question of waste heat boilers. I think a good many of us have tried them. Their efficiency is not high, unfortunately, and they cost a good deal of money. Secondly, there are regenerators, of the Siemens type and others, but they are not really satisfactory, I think, for the ceramic industry. There only remains then the question of the possibilities of recuperators. Of these there are many good types on the market, all of them more or less efficient, and many of them more or less complicated, but there is no difficulty in my experience in the construction of recuperators which do not bring in any bewildering complications. In one works, I built recuperators which have been in use since 1908, and there has never yet been occasion to get inside them. In other cases of more recent installations which have been built for greater efficiency, the experience has been identically the same.

If I may just summarise in one sentence—The two economies to be considered are (1) greater attention and care to the modification at small outlay of the arrangements for the gasifying and burning of coal; and (2) the recovery of waste heat, and its utilisa-

tion for preheating the air required for burning of the coal.

Mr. J. H. Marlow:—Sir Arthur Duckham and Dr. Smith in their remarks both seem to have taken my paper and explained my tunnel. They say that you want—and I agree with them—first of all a producer, as perfect as can be devised, in order to make the gases; (2) a combustion chamber, and (3) preheated air. Now in my paper I have explained that in my tunnel I have preheated air, superheated gases and what I think is a very simple and very effective producer, in which the gases that I require are produced at a very low cost indeed. There is only one point in regard to which I differ from Sir Arthur Duckham and Dr. Smith, and that is this: to run the tunnel I have found that I do not want experienced men, but those who, whilst knowing nothing, will do just as they are told. At first I picked out some very brilliant workers—men who no doubt knew something about gas-firing, but they always had some pet idea of their own, which, whenever I was not on the spot, they immediately endeavoured to put into practice. I was compelled eventually to dismiss these men, and now I have six men running my tunnel who, if you tell them to do anything, simply do it at once. That is the only point in regard to which I differ from my two friends. There is no doubt about it that the three essentials are, as stated, (1) the producer, (2) superheated gases, and (3) preheated air. Afterwards, to get the heat is a very simple matter. It can then be distributed purely by measurement, and very much more simply than most people seem to think.

A point that ought to be more appreciated, I think, is that a tunnel oven lends itself to the organisation of a factory. Your sorting or biscuit warehouses can be at one end, and your receiving warehouses and packing house at the other end. This makes handling very simple. The goods simply pass through the tunnel oven as you would have sausage passing through a sausage machine. What then is there to stand in the way of a tunnel oven? Is it the cost that frightens you? If it is, it should not be. Take your ordinary 16·6 ovens, which cost you to-day more than a thousand pounds each to build, and compare the cost with a tunnel oven. I am prepared to build you a tunnel oven 280 ft. long 8 or 9 ft. high, which will give you a capacity of six ordinary ovens a week, for £4,000. How many bricks do you use in your old type of ovens? Four such ovens will give you a yield of 60,000 bricks. I have pulled down four of the old ovens and used these 60,000 bricks in the building of my tunnel. From this it will be seen that cost should not stand in the way.

I have said before, and I repeat it now, that it is my belief that a tunnel system of firing both for the potting industry and the refractory materials industry, must before long come into general use because of the advantages that the tunnel oven offers in the way of reductions in costs of production. The tunnel oven will enable

you to attain to better organisation of your factory, which in turn will enable you to reduce your costs considerably. I am quite confident that it will not be long before we shall see many more tunnel ovens built and far fewer of the old bottles standing. If you could only realise—as my firm have realised—the benefits which are to be derived from using this method of firing, you would be bound to come to the conclusion that initial cost cannot be allowed to stand in the way.

Mr. H. J. C. Johnston:—With more or less forethought I declined Dr. Mellor's invitation to take part in this discussion, because I regard myself more as a student of this subject than as a "symposiumist." I would like, however, to say a word or two on some of the points that have been raised this afternoon. I think we must not lose sight of the fact that this is the Refractory Materials Section of the Society. A good many of the arguments that have been advanced refer to the ceramic industry as a whole rather than to the refractory materials industry in particular. Several of the speakers to-day appear to have lost sight of the fact that in many parts of the country refractory materials are already burned in continuous kilns. Figures have been quoted to-day, as they were also quoted in the discussion at Stoke, which could not by any stretch of imagination be taken to relate to coal-fired continuous kilns. Our chairman himself pointed out at Stoke that he was burning firebricks up to 3″ or 4″ thick to a temperature of cone 9 down, with a consumption of fuel ranging between 1·8 and 2·2 cwts. per ton of material fired, and I may say that our experience has been similar to that. With all deference to the gentlemen who have given us these interesting facts in relation to the hydro-carbons and the rest of it, I believe that what is wanted in this discussion is something in the nature of definite evidence as to the saving which may be obtained by the use of gas-fired kilns as specially applicable to the refractory materials industry. I am afraid I can find nothing either in the already published discussion or what has been said to-day that gives us, with any degree of definiteness, what saving is to be obtained by applying gas-firing to refractory goods in the place of the coal-firing in continuous kilns, which is already common practice.

Dr. Smith suggested that the difficulty which stood in the way was lack of money. I am certain that there are a number of manufacturers in this country who are quite prepared to spend money on gas-fired kilns if the necessary evidence of economies can be put before them. If our industry is in the acute position that has been represented here to-day, it seems to me that what we want to do is to stop talking about the various methods, come to some definite conclusion on the point and get ahead with the erection of the kilns. We have had one discussion at Stoke; we have had another here to-day; and if we go away from this meeting

without some conclusion having been reached we shall no doubt be having another discussion in Sweden next Spring, and probably be as far off our mark in the end. Is it not possible to arrive at something more definite than we have arrived at as yet ? Mr. Ridge appeared to dangle a bait in front of us, but he withdrew it so quickly that we could hardly see it. I understood that he was about to tell us of something which would save us 40 per cent. of our fuel. I was waiting for him to explain what this simple and effective thing was, but instead he went on to something totally different. I do not minimise for one moment the problems connected with the scientific side of the subject, but I would like the chairman to add a word or two to what he said at Stoke last year, and what he has also said here to-day bearing on the practical side of the application of gas-firing to the refractory materials industry.

Dr. M. W. Travers:—If, after the remarks of the previous speaker, I might perhaps be permitted to say a word or two on the theoretical side, I would just like to say that it is necessary, before we attempt to do something further, to be quite clear as to what it is that we are already doing. I have found in the glass industry that there is a good deal of confusion as to what is really implied when we speak of direct firing. There is an organisation known as the American Bureau of Mines, and they published some time ago a bulletin which they had the goodness to send me. In one of the papers was described a series of investigations in regard to what were called direct-fired furnaces. The coal was thrown on to bars and fed with air from below. It was shown that in every case the whole of the oxygen had disappeared before it had risen four inches from the fire bars, and that in every case the gas which came from the top was what might be called a fair producer gas. Every so-called direct-fired commercial furnace is actually a gas producer, in which the gas is sometimes burned by secondary air, but very often is not burned. Now if we can get this word "direct-fired" out of our vocabulary and come to regard all fires as producer systems, in which the fuel is more or less efficiently gasified, and in which, above the fuel bed, the gases are more or less efficiently burned, I think we shall arrive at a better idea of what we are doing.

I am afraid that I cannot agree with the statement made by previous speakers that you cannot burn producer gas with cold secondary air, and that it is absolutely necessary to heat the air. The fact is that preheating the air usually furnishes the only method of getting it into the furnace. We had built glass pot furnaces in which the air and gas met in a central eye, but while in some of these furnaces the air was preheated recuperatively, in others it was practically cold when it mixed with the gas stream. When the furnaces were not furnished with recuperators the air

was injected by means of a fan. The total efficiency of the recuperative furnaces was much higher than that of the non-recuperative furnaces, but the difference had nothing to do with the difficulty of burning the gas with cold air, for no difficulty had been experienced.

The fact that furnace builders regarded the problem of introducing secondary air into furnaces as one involving statics rather than dynamics was the cause of failure of many furnaces. One had not merely to consider whether air would flow through the channels in a certain direction, but whether the rate of flow would be sufficient to provide for the complete combustion of the gas.

Mr. Woolf:—Before the discussion is closed, I would like to say that when I referred to you in England as being backward, I did not intend to refer to your methods. It was not my intention to criticise your manufacturing methods, although I think you could certainly improve them. I believe that Canada can learn a lot more from you than you can learn from Canada.

A question that was brought up in connection with my paper was that of radiation. I believe the remark was made that radiation should not be used for heating. That would be true of a low temperature furnace, but on a high temperature furnace it is quite possible to get 3,000 degs. F. on one side and a very nice temperature of 2,500 degs. F. on the other side. That is the method that we have been trying to work out in our kiln, and I think we have succeeded.

With regard to the question of using city gas in preference to oil, the main reason that gas is being used at the present time in industrial furnaces in the States is that manufacturers have been using natural gas, which is fast giving out, and it is cheaper to come to the city and buy gas from the city mains than to rebuild the furnace for oil.

Comparing city gas with oil at the present respective costs gas comes out about eight times as dear as oil. At the same time, as I have already stated, the furnace which I have been describing to you is just as applicable to gas as to oil. The main thing to bear in mind, whether you use gas or whether you use oil, is that the system lends itself so much better to continuity and ease of working and therefore helps to solve the problem of labour and the other allied problems with which you will all be sufficiently acquainted. In all sincerity I say that anybody can operate an oil furnace if only he will use a modicum of that intelligence with which nature has endowed him.

Lt.-Col. C. W. Thomas:—In winding up the discussion, may I say that I think Mr. Johnson has rather hit the nail on the head, for there was noticeably at Stoke, as there has been here to-day, a tendency on the part of some speakers to lose sight of the fact that we represent only the Refractory Materials Section

of the Society, and, as I indicated at the outset, although I did not say it specifically, our problems in the direction of firing are certainly very different from those of our friends in the other branches of the Society, whose activity is directed to the manufacture of earthenware, porcelain and the like. But it still remains a fact that even in refractory works, the conditions vary, as between one works and another, both in regard to the type of kiln employed and its size, quite apart from the method of firing it. The most efficient type of kiln theoretically will not necessarily operate with equal success at two or more works.

One or two references have been made—notably by Sir Arthur Duckham—in favour of the man who is using coal-fired kilns, whilst his neighbour with gas-fired kilns is sitting up at nights in order to see that nobody plays the fool with the producer. Had there been an opportunity I would have liked to ask Sir Arthur Duckham one or two questions, because at one of their works in my district I happen to know they have no coal-fired kilns, but a gas-fired continuous kiln. Evidently they *have* solved the question of having to sit up late o' nights to watch the producer !

Mr. Johnson has referred to some remarks I made at Stoke. I see no reason to alter the opinions that I then expressed on these particular points. It is an undoubted fact that if you convert fuel into gas you lose approximately 20 per cent. of the available heat of the fuel in the producer. Of course, if you work your producer as an integral part of the kiln itself you may save some of that, but you do not save all of it even then. If you have a central producer and take the gas through to the successive chambers of a continuous kiln you must of necessity lose a considerably greater proportion of the fuel energy of the coal. You lose some in heat losses; you also lose some in radiation losses in the flue. But in these cases it seems to me you have to work out for yourself a sort of heat balance. On the one side of the balance sheet you must put the probable losses in fuel through the adoption of producer firing and the conveyance of the gas from a central producer, and similar losses; on the other side you must set down your savings. You may no doubt be able to make a saving in labour costs owing to delivering all your fuel at one point and dealing likewise with all your ash at one point, for it is easier to apply mechanical means of handling fuel in bulk, than when you have to distribute your fuel around a number of kilns. But the fact remains, I think, that whatever economies there are, will be found to result not from a mere change over in system from using solid fuel in a fire hole to gas from a producer, but the problem will resolve itself into a question as to whether you do or do not use recuperation in heating.

In a continuous kiln—whatever may be the type of firing—you do make use of recuperation because you take your secondary air through a burning chamber where it gets very nearly as hot as

the combustion chamber in which you desire to burn it. You take the secondary air, pass it through a chamber that has been fired, and after heating it up in that way you allow it to come into contact with the gases coming off from the producer in the chamber under fire. You then conduct the waste gases from the chamber under fire through one or more successive chambers where they preheat the ware that is subsequently to be burned, and, when you reach a point where you have taken so much heat out of the gases that you have cooled them, you stop. That point may be one, two or three chambers ahead of the firing chamber. Beyond that stage you want to bring in fresh air by means of a separate flue of some kind from a cooling chamber where the bricks are at a temperature of 300-400 degrees C., passing this down over the green ware, and through a separate damper into a separate stack, because, if you bring along water vapour into a chimney stack, as has already been pointed out, you will help to kill the draught. I think that in the various specifications of kilns—continuous and otherwise—that I have amused myself with in my spare time, I have only found two in which this fact has been dealt with, and where the design has provided for a separate flue and a separate stack to take away the vapour-laden air, coming from the chambers charged with green ware which has been dried by introducing air from cooling chambers.

Mr. Johnson asked, in effect, what useful purpose has been served either by the discussion at Stoke, last year, or the adjourned discussion here to-day. I am afraid that is rather a difficult thing to gauge, because one does not know quite what views other people have taken, and what (if any) improvements they propose to give effect to in their own works. But one point may be of interest. I believe the Fuel Research Board, at the request of the engineering brick people, have undertaken a definite investigation into the various kinds of kilns in use in the brick trade, with a view to deciding what is the most efficient kiln for their particular purpose. The Fuel Research Board are interested, because naturally they want to conserve the supplies of fuel that are available, and incidentally the brickmaker is interested, for he does not want to burn any more fuel than he is compelled to burn because he has to pay for it. I think the concensus of opinion is that, out of the total amount of heat, even in the best continuous kiln, not more than somewhere about 10 per cent. as a maximum is made use of in the actual heating up of the bricks that are burned; the other 90 per cent. is lost in various ways.

Here again I think a point that deserves very much more attention than it has hitherto received is the question of heat losses through the ground or the walls either of the ordinary kiln or the continuous kiln. I have seen it stated in various papers that anything from 40-50 per cent. of the total heat in the fuel is lost in this way. It should not be a very difficult thing to apply

insulation of some type or another in the walls and the floor, whatever the type of kiln may be, and considering the immense margin of economy that there is, if the fuel losses are anything like what they have occasionally been stated to be, one would think that that is a point that we might very usefully devote our attention to.

Personally I think there are points in favour of gas-firing other than the mere questions bound up with economy, although these are, of course, vitally important. With coal-firing the control of temperatures and the control of time—which is an important factor—is not nearly so easy as it is with gas-firing. I will grant that you may have to have a different type of man to work the installation for you. It may be, and I think it is, desirable, and certainly it should be worth while, to consider gas-firing, because of the advantages that it offers in the matter of control, and because of the fact that you can attain more readily to these higher temperatures that are becoming more and more incumbent upon us from year to year. I do not think we have heard the last of the temperature at which a silica brick ought to be burned, and we have not heard very much at any time of the temperature to which firebricks should be burned. It may very well be that in the future the burning of all classes of refractories may have to be carried to higher temperatures than hitherto, and in that case I do not think there is any doubt that gas-firing will be found more suitable in many ways than direct-firing.

Mr. Johnson referred to some figures which I gave at Stoke. These figures, I may say, were quite correct. The type of kiln is an ordinary Belgian kiln with transverse grates situated at every 12 ft. and with about 2 cwts. of fuel to the ton of fired material we reckon to be able to get cone 9 down. Obviously if you have an internal grate you are liable to get a higher temperature over it than you would be able to get in the middle of a 12 ft. setting. But in the majority of cases the equality of the temperature throughout a large mass of refractories is not so important as it would be considered to be in the more precise industries. In the burning of porcelain, for instance, you must of necessity have a definite temperature and there are limits beyond and below which you must not go. In refractories, so long as you have a physically strong brick it does not matter whether you are 10 or 15 degrees above or below any specified temperature.

Perhaps Mr. Johnson will agree that we might quite usefully revive this discussion in a slightly different form, *i.e.*, not only in order to consider the question of gas-firing, but also the best types and sizes of kilns for refractories in particular. A great many people seem to have exercised their ingenuity upon this question, and most of them have directed their attention towards evolving something slightly different from what someone else has already patented. Anyhow, the principles are very much

the same in the general run of installations.

I have purposely refrained from saying much about tunnel kilns because I do not presume to know much about them, and I do not wish to be torn and rent by any of these advocates of tunnel kilns who are present with us to-day.

XIV.—Spit-out of Glazes on passing through an Enamel Kiln.

By Jno. Miles.

SPIT-OUT of glaze is *not* of itself the fault of any constituent of the glaze or body. In other words, it is not a body fault or a glaze fault—but is brought about by other influences entirely outside either body or glaze.

Description of Spit-out of Glazes.

Spit-out faults are really due to small bubbles of gas, which, coming chiefly from the pores of the body, pass through the glaze when the latter becomes viscous whilst in the enamel kiln, leaving the surface of the glaze more or less rough and undignified in appearance, this state being retained after the glaze has cooled down. Many causes give rise to this fault and blessed indeed is the potter who is *not* troubled with it. But I am going to take it for granted that all in this room are more or less familiar with it in some of its aspects.

Some of you doubtless have been exasperated on seeing a fine piece of pottery, perhaps beautifully painted and embellished with gold, rendered useless by this fault, which has taken place in the finishing stage of the piece. Others, namely, customers, manufacturers, ordermen and managers, have been sorely tried, when the completion of orders has been prevented by this same fault happening on various pieces. Some pieces have this fault so bad, that they ought never to be sold, even as *lump*, but should instantly be relegated to the pitcher basket. So much for the fault itself.

What are the causes? One cause which gives this fault in abundance is the effect of the fire on the glaze in the glost oven. Let us first of all consider whether the glaze during glost firing is being affected by some body outside itself, and if so, what is its nature? In the first place, on porous bodies, it certainly is being so affected and in such a manner that, under certain conditions, spit-out in the enamel kiln will inevitably occur. The gases which the pores of the body contain exert an influence on the glaze. This is due to the expansion of these gases under the influence of a rise in temperature rather than to any generation of gases that may occur by decomposition of the body constituents. This gas, in my opinion, is none other than water gas in the form of super-heated steam, and if any gases are forming by the decomposition of body constituents, then this is the factor

which is accelerating their creation. It is easy to see how, in the first stages, these gases come into the body pores. They enter in as water, whilst passing through the dip tub on glazing, and in my opinion, a lot of it comes out only by bubbling through the glaze, at a stage of glaze viscosity, as super-heated steam. Now, if your glaze is properly fired in glost ovens, these gases will make their exit, *i.e.*, if the glaze remains soft enough for a sufficent length of time. What is here meant is, that when finishing point is reached in glost firing, and the cooling down is not too sudden, the bubbles of super-heated steam will practically have fizzled out of the glaze before the latter becomes too hard and holds them. The pore-spaces of the body are refilled by the atmosphere of the saggar, whose gases do not expand so much as the super-heated steam.

On the other hand, if the glaze is suddenly cooled by immediate raising of dampers, throwing open of the fire-mouth doors, dropping of the clammings, or these and others all in combination, to get quick cooling, just when the finishing point in the middle of the oven is reached, then you will most certainly get a mass of bubbles one on the other ; yes, a perfect network, visible and invisible, in your glaze, which contain gas.

This condition of things will particularly apply to those parts of the oven where cooling sets in rapidly, just when finishing point is reached. The fewer bubbles the glaze contains, the more solid is your glaze, and the greater the resistance offered to any generation of gases that may occur in the enamel kiln, which go to make spit-out.

It may be thought that super-heated steam, generated in the body pores, would have fizzled out before the glaze becomes viscous on heating, but I hope to show later on in this paper that this is almost certainly not the case. The number of bubbles remaining in the glaze after the glost oven fire will depend very largely on the nature of the fire to which they are subjected in the enamel kiln. It is well to bear in mind, that an enamel kiln is fired up in about half the time of a glost oven, and that the gases in glaze bubbles are expanding in relation to the increase of temperature, the rapidity of expansion depending upon the rate of application of heat. Very rapid is the expansion of these gas bubbles, if, when the fireman suddenly finds out at 5 p.m. that it will take one, two or three more hours to finish his firing, he endeavours to get through in one hour or less. Then the fight for an increase in volume of the gas in the glaze bubble becomes so keen, that the resistance of glaze to bubble will be overcome and spit-out will ensue in abundance. The higher the heat reached in firing, the softer the glaze becomes, and the less resistant to any expansion of gas contained in a bubble imprisoned in the glaze ; and if it can be established, that the gas in the bubble is chiefly super-heated steam, then, the increase in volume of that gas being about 12·5 per cent.

for every 100° F. or 37·8°C., rise in temperature under N.T.P., we can imagine the effect of such a gas enclosed in a softening glaze under the influence of increasing temperature.

I know by experience that hard kiln heats (*e.g.*, 900°C. in muffin kilns) when suddenly cooled from the fired-up point, give a much greater crop of spit-out than when the kiln is allowed to cool with the clammings undisturbed, and the fire-mouth doors closed. This can, I think, be put down to the expanded gases in the bubbles suddenly contracting in volume with sudden cooling, and since the very thin glaze surrounding them is unable to follow so quickly, (thus causing a temporary vacuum) a spit-out or pin hole appearance of the glaze is the result. Again, the passage of these gas bubbles through the glaze on coming through enamel or hard kiln heats can be facilitated by additional fluxes, *e.g.*, those used in colours which are applied for decorative purposes to glazed goods, viz.: painting, groundlaying, etc. I remember an instance where oil of tar was the medium used to bring an artist's colours to a satisfactory working state, *i.e.*, to facilitate the application of colours to the ware, using a camel hair brush. It was demonstrated beyond doubt that this particular oil, whenever it was put on a piece of ware, either with the colour or alone, and passed through the enamel kiln, caused spit-out. Many probable and improbable theories were put forward as a reason for it, though I believe only one person could have given a satisfactory explanation. My own opinion is, that this tar may possibly have masked a soft flux, not put in unwittingly, but to secure a lusciousness, and individuality, which might have been possible with another type of body, and perhaps glaze, without spitting. These fluxes will soften the glaze (in parts) at a lower temperature and thus facilitate the breaking through of the gas bubble in the glaze, resulting in spit-out.

To minimise this spit-out then, we must see that the glaze is well fired up in glost ovens, particularly middle ware in round ovens, and where a porous body is in vogue on the works. The glaze will then be free from bubbles, more solid, and better able to resist any expanding gases that may be present in body pores on going through enamel kiln heats. Spit-out of glazes will also occur when moisture has been absorbed into the body pores of glost ware, which is then put through enamel kiln heats. Moisture from the atmosphere may be drawn into the body pores where the glaze is broken, *e.g.*, on the feet of goods, stilt markings, etc., etc. It may also penetrate into pieces which have been in contact with water or a moist atmosphere; for instance, water used in the process of transferring prints and lithos often enters the body, the pores of the body acting as the capillary system by which the water is taken into the body. It is useless drying these pieces when once the moisture is in the body, unless a right method is adopted. The point where the glaze is broken must, during drying, be the

topmost point of the piece. The moisture will in that way leave the piece and be replaced by the surrounding atmosphere.

Some years ago, a certain well-known firm were having trouble with spit-out. One of the lines affected was jugs, these being of the tankard shape, and rather short of glaze in places on the foot. During the process of glost printing, for kiln fire, they were put in water for the print paper to soften and to be sponged off in the usual way. It was here that the water was taken up into the body pores, and when passed through enamel kiln heats a great percentage of spit-out was the result. Let me here say that in the first place it was much easier to soften the paper by putting the articles in the washing-off bath wholesale, than by softening the paper with a wet sponge and removing the surplus paper afterwards. The latter should have been done. However, it was interesting to find that spit-out did not occur with these jugs when placed mouth downwards in the kiln, the following being done to verify this : jugs were saturated in water and afterwards put in the kiln, some mouth downwards and others on their feet, alternately. Those placed on their feet came out of the kiln spit-out, whilst those placed mouth downwards were entirely free from spit-out. The conclusion I came to was, that the steam generated in the pores fizzled out through the short-glazed feet of the jugs on those placed mouth downwards, whereas those jugs placed on their feet allowed no escape for the super-heated steam, except by forcing its way through the glaze, this being made possible by the ever increasing volume of the gas together with the softening of the glaze on a rise of temperature. I think the above bears out my theory that super-heated steam, generated in the body pores, having entered in as water during the glazing or dipping process, may not be altogether fizzled out of the body, even on passing through the glost oven ; then in the enamel kiln it may resume its already nearly accomplished journey and find an exit through the glaze, causing spit-out. I think one can easily imagine the effect of the pressure of an increasing volume of super-heated steam making its way from the pores of the body into the glaze, and through it ; and how much more readily will it accomplish its task if the glaze has already, even to a small degree, bubbles containing gas in one form or other.

One must imagine these bubbles side by side, one on the other, with a small division of glaze between them; first one division giving way, and then another, under the pressure of the increasing volume of gas, until the gas finally forces its way out, causing spit-out. Everything possible must be done to prevent moisture from entering the body whilst being warehoused in the glost state. Dry warehousing is very essential,with a constantly warm and dry atmosphere and a room temperature of about 60° to 70°F.; at week-ends, the temperature of the room must be maintained within reasonable limits, for a fall in temperature will lead to serious

trouble. It brings about a contraction of the volume of the atmosphere in the room, which in turn brings in outside atmosphere, damp or otherwise. Exactly the same thing happens with the volume of atmosphere in the body pores, bringing in (by way of short-glazed parts) the changed atmosphere of the room, very often a humid one. It is very difficult to get rid of the damp atmosphere, which has been acquired by the body pores, on merely drying, unless the broken glaze, where it entered, is the topmost point during drying. Wherever possible, it is better to decorate and fire in the kiln immediately on coming out of the glost oven. Bubbles of gas in the glaze will often be seen at the bottom of articles when drawn from the oven; for example, jugs and such like, inside at the bottom, will be freer from bubbles than underneath the bottom of the same articles. If these articles had been reversed in the oven during firing, the opposite effect would have been obtained. This I think is accounted for by the fact that the gas as a rule finds it easier to go up and out, although some of it is naturally depressed downwards, and when cooling sets in, the downward pressure is much relieved by the contracting volume of the gas. The natural tendency will then be for it to move upwards. But the glaze is hardening, and some of these gases are imprisoned as bubbles in the glaze, whilst those which have already made their way into the glaze at the bottom of the inside of these articles, find it easier to get through and dissipate themselves into the inside atmosphere of the pieces, then into the atmosphere of the saggar and out into the oven itself through fissures of the saggars and broken wads. Again, it is much harder for these gases to pass through, from body pores, into and through thickly glazed pieces, than is the case with the thin glazed pieces and doubly hard if the thick glaze happens to be underneath the glazed articles. It may be that bubbling or boiling of glaze only occurs where gases are present either underneath and in direct contact with the glaze (*i.e.*, in the body pores), or by comparatively rapid decomposition of the glaze itself; and when the glaze is soft enough, these gases present or being formed, will do their best to frizzle out. If this happens during enamel kiln firing, the result will be spit-out of the glaze.

The surrounding atmosphere in the enamel kiln, *i.e.*, oxidizing or reducing, as the case may be, has, in my opinion, practically nothing to do with spit-out, unless the atmosphere of the kiln contains a softening action on the glaze, *e.g.*, a lead laden atmosphere coming from a quarry wash which has been and may, perhaps, still be sometimes used. A sulphur-laden atmosphere would, I think, have a tendency to harden the glaze and of course, cause other troubles. I do not think that *old ware* of itself will be a cause for spit-out, though the atmosphere of the body acquired by age and contamination will affect the glaze Then again, I do not think that any carbon dioxide which may be generated (although I do not think that much CO_2 is actually generated during kiln firing) in the body pores by any

decomposition of body constituents will of itself cause spit-out. Super-heated steam would, I think, accelerate the creation of carbon dioxide, but the prime factor in causing spit-out will be the super-heated steam itself. I have bedded a semi-porcelain, porous body, in a solid flint bed and fired in a biscuit oven to between1,100-1,150°C; the pieces on coming from the oven showed a bad coloration, from grey to black. I had these glazed and fired in a glost oven, and found the bad colour still showed after the glost oven fire. I then sent these pieces again and again through the enamel kiln in places where spit-out is likely to occur (*i.e.*, hard places), but there was still no sign of spit-out. Slack firing of enamel kilns, as now generally constructed, is in my opinion, a mistake in more ways than one, but as regards spit-out the use of slack for kiln firing is almost certain to bring about factors that will create spit-out in large crops, that is, if there is any pre-disposed tendency.

In firing with slack, one can readily ensure, through the feeding mouths over the fuel, the necessary amount of air for the combustion of hot gases coming from and through the top of the fuel, but it is much more difficult for the essential amount of air for complete combustion of the gases to pass through glut bricks and firebars in and through a solid mass of fuel such as small slack would, under firing conditions, certainly give. It would cake and sinter together and make it almost impossible for any air to get through, giving no length of flame in consequence and at times a sure drop of temperature in the kiln. It is here the trouble takes place. The fireman comes round, looks into the glowing mass which shows a very short flame, gets his crowbar poker and bashes it into the soddened fuel, with the following result: a sudden burst of heat and flame comes forth from the violently disturbed mass, which sends a great volume of heat units bounding into the flues and round the box of the muffle kiln, sending up the comparatively low temperature of the inside kiln with a leap. Consequently the gases in pores of the body or contained in any bubbles in the glaze (whatever they may be) will want to expand suddenly and increase in volume. If, then, the glaze is not hard enough to resist this pressure, the gas will break through the glaze, giving spit-out. I would advise that slack be not used for enamel kiln firing, particularly by manufacturers of good class pottery. If slack is used, see to it that a proper well-kept book to tabulate faults from the kiln is at hand and a careful analysis of the same is made once a week, noting particularly the spit-out and sulphur lines and so face the truth unflinchingly, ruling out any pet ideas of kiln construction, etc. Again, do not forget the human element when slack is being used for this purpose. Do not tire it too long or too often, or you will sooner of later discover your mistake. However much one may attempt to gloss it over, the result from kilns under these conditions will not be good. The best type of fuel for kiln firing (after lumping off with lump coal),

is small cobbles, say cobbles to a hardening-on heat of 650°C., then nuts or big beans for finishing. A good clean fuel like Cocks-head is suitable. The tendency for hard-fired biscuit ware to spit is very great—and here I am a bit puzzled—but I think that one of the reasons is that it is not altogether non-absorbent. Further, the pressure of the gases on the glaze is not relieved, as in the case of open porous bodies, in which the expanding gases fill to the utmost the pore spaces, so that their only escape is through the glaze, spit-out being the result. It is also possible and probable that small volumes of gases are contained in small pockets sealed up near the surface. When in contact with a softening glaze, these enclosures are released and cause spit-out in the enamel kilns. Hard-fired biscuit is very much more susceptable to spit-out with a fitful, jumpy fired kiln. Again, one finds spit-out all over some pieces, on others in patches, inside holloware, and on various parts of pieces, and those pieces fired near to quarries of kiln have a much better chance to get rid of their bubbles than those that are cased away from the side of the kiln.

Spit-out inside hollow-ware. It is evident, in my opinion, that the expanding gases have taken the least line of resistance, the pressure of the hot gases surrounding the outside of the hollow-ware piece being greater than the inside pressure. Cups, especially hard biscuit fired, will more often than not spit-out more freely inside at the bottom when placed on their feet, but if they are reversed, the contrary happens, and if there be dry parts on the feet the spit will be greatly minimised. Again, a tier or height of hollow-ware in a kiln will be more prone to spit-out if it has to deal with the same heat units as, say, a solid tier or height of flat-ware or saucers in the same kiln. The expanding gases in hollow-ware pores, or bubbles in its glaze, will want to expand much more rapidly, often causing spit-out. I believe it is quite possible to fire a kiln full of hard fired biscuit for enamels up to 800°C. without causing very much spit if the fuel is suitable, and if the fireman will carefully regulate the heat of his kiln, especially from 650°C. to finishing, maintaining a constant but very slow and even rise in temperature, without fitful jumping. Again, I feel sure that in bodies that are non-absorbent the percentage of spit-out of glaze would be very low, *e.g.*, in vitreous, non-porous hard paste porcelains and such like. But the glazing of these bodies will be much more difficult than a porous body. I think it is possible for one to conceive an outside glaze spitting out; what I mean is, a glaze in which one or more of its constituents decompose or react to decompose other constituents when fired in a reducing or oxidizing atmosphere in the kiln. I have observed that ware, the pores of which have been more thoroughly plugged up by various methods in its process of manufacture, is not so prone to spit-out. For instance, pieces that had been thoroughly sponged and well flannelled all over, came out satisfactory. Patches

inside hollow-ware, where it may be a little difficult to get at and less likely to be effectively sponged, should have attention from the sponger. I think it is agreed that in clay polishing, *i.e.*, sponging, flannelling, knifing, in thrown and turned pieces for instance, or the backs of hand-made dishes, the pores are more or less likely to be blunted and "top filled" at the surface, which would to some extent give a greater resistance to any expanding gases met with in the oven or kiln. I have noticed that the backs of jollied plates seem more prone to spit than the surfaces of a flannelled plate. I think the dust in this case will partially fill in the pores and sinter to the body in biscuit firing, thus offering a greater resistance to any subsequent expanding gases.

Conclusions. To eliminate spit-out as far as possible, the following points are to be observed:—The clay must first be thoroughly and efficiently polished and sponged; the glaze must be well-fired in the glost oven, care being then taken to cool slowly down to about 900°C-800°C., after which the rate of cooling may be accelerated at will. Dry warehousing is essential; the goods, while in the glost state, must be kept free from contact with moisture; transferrers and lithographers should be very careful in the use of water in sponging off the prints, etc. The temperature of the glost oven should be made to rise as quickly as practicable from 800 to 900°C. to burst the glaze bubbles, but much more slowly from this point to the finishing temperature, to avoid crooked and blistered ware. There should, in general, be a steady, and not fitful, rise in temperature throughout—a constant gradual rise, particularly between 700 and 800°C. or thereabouts in kiln firing.

DISCUSSION.

Mr. A. G. Richardson:—We can all agree with one statement that Mr. Miles has made, and that is, that most people are very well acquainted with spit-out, and therefore, if the recipe that Mr. Miles has given us at the finish of his paper is really efficacious, we shall all be very grateful to him. However, I suppose a good many of you have your own ideas about the matter, and we shall be very pleased to hear them.

Mr. Ashley Myott:—I think every potter present will agree with Mr. Miles that the problem of spit-out is one which demands our earnest attention. As a practical potter, one cannot imagine anything more objectionable than getting one's goods right through to the glost warehouse, and then passing them through the enamel kiln, only to find that all one's efforts have been in vain, and that the order must be begun over again. I am afraid that too often in the past we potters have been inclined to put too much responsibility for spit-out on the poor kiln fireman. We know that he has his responsibilities; we know that he certainly is responsible for some

of the fault; but by no means is he responsible for the whole of it.

Like many others in the room, probably, I would like to have considerably more time to digest the paper, and to think out all the various suggestions which have been put before us with a view to curing spit-out, and I certainly feel that we are all very much indebted to Mr. Miles for the suggestions which he has offered. Possibly there will be many members who would like to ask him questions on the various points.

I have often noticed myself that, although cups on our works are fired pretty hard, we get a far less percentage of spit-out amongst cups than we do in the other hard-fired hollow-ware. Perhaps Mr. Miles may have some suggestion which will explain why cups show a less percentage of loss from spit-out than other hard-fired ware.

Mr. F. S. Worthington:—I agree with Mr. Myott when he says that the paper has been a most valuable one. It reveals very careful thought, and I should think many years of experiments and trials. There are, however, several statements in the paper which I would like to criticize. To begin with, I would like to bring up a question with regard to the quick cooling of the enamel kiln. I am inclined to think that if Mr. Miles keeps a careful record he will find that the majority of the spit-out is experienced on a Monday. Now, that kiln has been fired on a Saturday—very often a football day. The point I wish to put is, that the doors of the kiln are not opened until the Monday, and yet—it is my experience at all events—more spit-out is found in that kiln than in any other kiln of the week.

Another point which I do not agree with at all is the view expressed by Mr. Miles in regard to the slack firing of enamel kilns. My experience—and I think it is the experience also of others, at the works of which I am the manager, and which, I have confidence enough to believe, turns out as good a quality of earthenware as anywhere—is that slack firing during the war and during the coal-strike occasioned us a great deal less loss than we had when we fired the kilns with Cockshead coal. Personally, I think it is a very great mistake to use nuts or cobbles, because when you put nuts or cobbles on a fire, as everyone knows, you get a terrible flash. If you use slack you do not get that flash; nor do you get it to any great extent when you put on big coals.

There is another question that I would like to ask, if I may. Mr. Miles mentioned tankard jugs. I do not know whether those tankard jugs were turned or not, but I raise the question because I believe, as a rule, a tankard jug is a turned jug. Now if these jugs were turned, then the pores of the body would no doubt be filled up on the lathe in very much the same way as when flannelling the wares, which Mr. Miles spoke about.

There are several other points which I will not enter into just at the moment; at the same time, I must express my appreciation of a very valuable paper, and one which I am sure the majority of

us will be pleased to go through more carefully in its printed form.

MR. MILES:—If your furnace is properly heated you do not get a terrible flash, from cobbles or nuts. It is when the pent-up heat in a soddened fire is released, that you get a terrible flash. There is a very sudden increase in temperature of the body under fire, whilst bating with dry small slack would give you all flash.

I thank Mr. Myott and Mr. Worthington for their appreciations. The paper has certainly taken me quite a long time to prepare. It is quite possible that I may be wrong in some of my deductions, but I want you to disagree with me, in order that it may be proved where I am wrong. I would like to ask Mr. Worthington if he is still firing with slack.

MR. WORTHINGTON:—Yes; very often.

MR. MILES:—Well, if you are getting good results I should continue.

MR. WORTHINGTON:—I do.

MR. MILES:—If the results of the kilns drawn on Monday are the worst of any during the week I should be disposed to get a fireman who is not interested in football. Whatever the reasons are for rush firing, it will, in enamel kilns, tend to cause spit-out, especially where gases are being generated in body pores, the more so if superheated steam is the particular gas present.

MR. WORTHINGTON:—But that does not explain anything about the opening of the kiln doors. And in your paper you say that if a fireman suddenly finds out at 5 p.m. that it will take one, two or three hours to finish firing, he endeavours to get through in one hour or less. Will not this cause spit-out ware whether the kiln doors are opened or left closed?

MR. MILES:—When I mentioned the opening of the doors I was referring not to an enamel kiln but to a hard-kiln, which is a hundred degrees or so higher in temperature than an enamel kiln. But wherever rush firing occurs, especially between 700 and 800 degrees, most likely the same thing will result.

MR. WORTHINGTON:—Whether the kiln doors are opened or not?

MR. MILES:—Yes. But when I was speaking about the opening of the kiln doors I was speaking of a hard-kiln, which is rather different from an enamel kiln heat.

So far as Mr. Myott's question is concerned my experience is that we get rather more spit-out in hollow-ware than we do in cups. That seems to be the reverse of Mr. Myott's experience.

MR. MYOTT:—I am afraid Mr. Miles has misunderstood me.

My experience is that we get more spit-out in hollow-ware than in cups, although the cups are hard-fired.

MR. MILES:—That is our experience also. I think the cause is probably the inefficient sponging, and the atmosphere that is acquired during the stocking of the ware in the glost warehouse. Cups, as a rule, are more completely covered with glaze, whereas hollow-ware is more liable to absorb moisture through stilt marks and dry feet.

Returning to Mr. Worthington's point about tankard jugs. These were turned, but it is significant that the ones that were inverted in the kiln did not spit-out, whereas those which were placed on their feet did. I cannot see any explanation for these spit-out pieces other than that of the effect of superheated steam (mainly in its expansion, which is 12% for every 100°F. rise in temperature.)

MR. WORTHINGTON:—Then the facing of the ware does not have anything to do with spit-out?

MR. MILES:—What I was endeavouring to show was that the superheated steam was unable to get out when the jug was placed on its foot. Where that superheated steam becomes hermetically sealed, it causes spit-out, but where its escape is facilitated, spit-out is prevented.

MR. WORTHINGTON:—At the end of Mr. Miles' paper it was mentioned that when the ware was well flannelled and sponged and the pores therefore filled up, the ware did not spit out so much as with inefficient sponging and flannelling. The point I raise is, that when tankard jugs are turned, the pores will be filled up quite as efficiently as by flannelling and sponging.

MR. MILES:—Where the pores are topped and blunted there is less liability towards spit-out, for there is a greater resistance to the expansion of the super-heated steam. The resistance to the expansion of superheated steam depends upon the number of blunt pores.

MR. B. J. MOORE:—As there are many of us here, no doubt, who have other theories on spit-out, in addition to those which Mr. Miles has propounded, I think it would do good to the discussion to consider something on the lines of the relation that the biscuit fire has to spit-out. Mr. Miles seems, throughout the whole of his paper, to have dealt with cases of spit-out due to the glost firing and certain conditions which arise during the firing of the enamel kiln. I am of the opinion that there is a good deal of spit-out due to inefficient biscuit firing, and I think that some discussion on this point would be of interest.

MR. BERNARD MOORE:—I was hoping that there would be

considerable discussion on this paper. When I heard that there was going to be a paper on spit-out, I was very pleased indeed, for it is a subject in which I have taken a great interest for quite a long time. Whilst, however, appreciating the work that has been entailed in the paper, I do not think we should be doing justice to the subject if we do not express the opinion that Mr. Miles' suggestions have not added very much to the sum of our existing knowledge on the subject.

A good many years ago—I think it was in 1905—the following views were published in the *Transactions* in a paper I read on Brown china: "Brown ware is often produced without spits, so spitting-out is not an essential factor. *Moisture is the important factor* and a spit-out specimen can be produced more or less at will."

I think it would be a great mistake if we assumed that a body has nothing to do with spit-out. There must be many gentleman in this room who are aware that there are types of bodies which do spit-out. Mr. Miles has himself said that he cannot quite understand why certain bodies spit-out. I am referring now to various types of vitreous and hotel bodies. In my own experience one of the bodies that was most successful so far as selling was concerned had to be discontinued because it suffered to much from spit-out. This was a body that exhibited a very close surface. A biscuit piece was examined carefully in order to prove that there was not the least absorption. Whilst, therefore, I quite agree that moisture is one of the great causes of spit-out, we must be careful to remember that it is not the only cause.

There is another point that I might venture to criticize in Mr. Miles' paper. He seems to say that it does not matter very much what the atmosphere inside the kiln is. In my opinion that is one of the most important considerations. You have an atmosphere inside the kiln very often when it is red that will not support combustion. If a kiln is not ventilated properly—that is to say, if the atmosphere is not continually changed—you are raising the temperature of your ware in an atmosphere which will not support combustion; and when that is the case any carbon that is in the body will be raised to quite a high temperature before the atmosphere of the kiln changes to an oxidising one. It then burns too quickly; indeed, with explosive violence.

There may be some of you who may remember that I showed some years ago a specimen of body spit-out. It is perfectly easy to make one. Some biscuit ware without glaze will spit and you can get a lot of pock marks all over it. It is evident, therefore, that the body may have a great deal to do with the fault. If Mr. Miles will pardon my saying so, he has assumed that the fault is always due to superheated steam. In the earlier part of his paper he mentioned that he would endeavour to show that this superheated steam still persisted in the body when it came out of the glost oven. To quote Mr. Miles' actual remarks on page 2 of his paper: "It

may be thought that superheated steam, generated in the body pores, would have fizzled out before the glaze becomes viscous on heating, but I hope to show later on in this paper that it is almost certainly not the case." Now I fail to see that he has given us any evidence of this at all. He has told us, quite correctly, that the biscuit ware sometimes absorbs moisture which causes spit-out. Some bodies absorb moisture more readily than others and these are liable to spit.

When I came to read over a paper which was written about 13 or 14 years ago by Dr. Mellor and myself, I noticed that we attached at the time very great importance to the influence of moisture. In our opinion at least 80 per cent. of the spitting that occurred in pottery was due to the presence of moisture or organic matter in the body. And we went on to say: "This possibly explains why the cause of spitting has hitherto proved so difficult to diagnose."

I only wish to add one other little point to that. A great many people recommend that the glost warehouse should be kept very warm, so as to get the ware thoroughly dry, thus preventing spit-out. This, however, is very much like many other remedies in potting. We must take care that we do not overdo it. In my opinion you can actually produce spit-out by drying your ware too much. It seems rather a curious thing to say, but I think the explanation is more or less easy. If you dry your ware and keep it a long time in a very dry condition, and you afterwards bring it into a moist atmosphere, it is then very much more liable to absorb moisture than if it had been kept in an even temperature.

I would like Mr. Miles to inspect some samples that we have here of body spits due to carbon.

MR. MILES:—Apparently Mr. Moore seems to think that carbon has a lot do with spit-out. I should rather think that it would be very difficult for carbon gases to generate from particles of carbon that had got into the body, seeing that the carbon particles become so intimately mixed with the body and that the distribution is facilitated by the body fluxes and the subsequent firing; consequently a union is formed that would not easily be interfered with in the enamel kiln. If spit-out is chiefly due to the generation of carbon gases in the body pores, why should not spit-out occur in the oven, because in cooling an oven you get down to the temperature of the enamel kiln. One might say that the saggar atmosphere is against the creation of such gases in the body pores, but there are saggars that crack and break, and their contents, at 850°C. or lower heats, must be in a thoroughly oxidising atmosphere. If there were any tendency for the creation of carbon monoxide gases surely it must occur at that period. Yet who has seen spit-out from the oven?

MR. MOORE:—Oh! it is quite common.

MR. MILES:—I have not yet seen it. It has not been a common

experience with me. At all events I find that those pieces in connection with which there has been evidence of a split in the saggar, which most of you will agree causes sulphuring, have displayed very little tendency to spit-out, and one cannot deny that such pieces must have had a thoroughly oxidising atmosphere. Again, supposing one takes a mixture of lamp black and water and introduces this into the body pores of a glazed jug by allowing the jug to absorb the mixture, afterwards getting rid of the water, and sending the jug through the kiln. I do not think that if the water is entirely eliminated the carbon left behind will cause spit-out. It can remain in the body and in the glaze after the kiln fire. It is rather a tricky experiment and will require some watching. No half measures must be taken to get rid of the moisture before trying it. But if the water is properly got rid of I do not think spit-out will occur.

Mr. Moore has spoken of body spit-out. I do not know exactly what Mr. Moore and Dr. Mellor are referring to, but I think it is quite possible to make a body spit-out. I will tell you how it can be done. If one were to place steam pipes through the glost warehouse, and allow glazed pieces to come into contact with the condensed steam from blown joints so that the pieces are thoroughly saturated, afterwards passing through the enamel kiln, spit-out will assuredly occur, but it is a peculiar kind of spit-out. That can be attributed not only to superheated steam, but to alkaline solutions used in the boilers for the purposes of water-softening. In connection with porous bodies such a kind of spit-out does occur. Moisture of itself will not cause spit-out; *there is no moisture in superheated steam*, the *high coefficient of expansion* of which I specially wish to emphasize.

Mr. Geo. Price:—In some respects I differ from Mr. Miles as regards kiln firing. A good many years ago—in the days of the lustre band and sprig ware which never saw water from the oven to the enamel kiln—I was employed at a firm that was invariably in the habit of passing the glost oven ware through the kiln on the same day that it was drawn. But we got a good deal of spit-out. That ware has gone back again from the kiln to the oven for re-firing and has spit-out again; it has also been sent elsewhere to be refired in someone else's kilns, and again it has come out spit-out. Yet other ware in the same kiln has been good. We had ware sent to the same firm from other places which was fired in the same kiln and was good. So far as the spit-out trouble was concerned it occurred alike with quick firing or slow firing. Undoubtedly spit-out is a big problem. You can get it in all sorts of ways. I am inclined to think it is due to the condition of the ware itself, either in biscuit or glost firing (chiefly biscuit) more than it is to the enamel kiln.

Mr. Miles:—It is just possible that I may have been too confident in my assertion that the bubbles are superheated steam,

but whatever those bubbles may be—whether they are carbon monoxide gases or superheated steam, and I am inclined to think they are the latter—if you can manage to eliminate them you will practically eliminate spit-out. If the gases generated were carbon monoxide gases I do not think that the fitful jumps in temperature that the kiln sometimes gets would give that sudden rise in volume that would overcome the hardness of the glaze, whereas in superheated steam you have a different thing to contend with—a very great expansion in volume. Flash iiring in biscuit will certainly seal up any gases that are generated in the body after the flash firing period. These gases are under pressure and some are released under the softening influences of a glaze in glost firing, but not all, and more are likely to come out during enamel kiln firing. If the goods Mr. Price refers to were *not* flashed, biscuit and glaze being well fired up in the glost oven, it is difficult to see what caused them to spit-out. I am inclined to think that the fault in this case lies at the door of flashed biscuit or short fired glaze. I repeat that carbon particles which may be left in the body, that is, of normally fired biscuit, will not cause spit-out.

Mr. Steele:—It seems to me that Mr. Miles has convinced himself in regard to the various points that he has raised, and I think that others of us might do well to raise other questions that have come under our own observations, such as that mentioned by Mr. B. J. Moore, viz:—The carbon theory and inefficient biscuit firing. Mr. Moore, Sr. said that he could give us instances where spit-out has been caused in the enamel kiln by using a clay in the body very high in carbon. Some of us have had experience of that, and we have ascertained that by eliminating that clay high in carbon, the spit-out has either disappeared altogether or been reduced to a minimum. I would like to ask Mr. Miles whether he can explain to us, looking at the problem from another point of view than superheated steam, why it is that we so often get spit-out in the enamel kilns with hollow-ware which comes from the ring in the biscuit oven, and which, if the fireman does not go steady with his firing, is the most liable to get flashed. Our theory is that the carbon in the body is enclosed in the early stages of the firing and is thus prevented from getting out. Therefore the carbon goes through to the enamel kiln and spit-out ensues.

Some of us know that we have practically cured spit-out by firing biscuit ovens slowly. I can give you a personal observation where I had a considerable quantity of spit-out, and the biscuit fireman, although we argued with him that he was not soaking his oven sufficiently, would not agree. We took the biscuit firing upon ourselves, firing in the initial stages more slowly, and aiming at driving out all the gases and the carbon that we suspected were being imprisoned. I traced through the experiments very carefully myself, and ascertained that by that means, beyond a doubt, we got very little percentage of spit-out ware in the enamel kiln.

I may point out that on that particular firm there is no such thing as wet glost warehouses or excessive moisture coming into contact with the ware at any stage. Everything is perfectly dry, or as dry as is practicable. The facts before us are that spit-out was cured by slowing down the biscuit firing. There were no other factors entailed in regard to the gases. I would like Mr. Miles to confine himself to this point, and explain to us, if he can, how it is that you can cure spit-out by going slower in the biscuit oven, thus facilitating the escape of the carbon from the body.

Mr. Miles:—I can only say in reply to that question that you can introduce carbon into the body pores and it will not cause spit-out. For instance, you can introduce it as lamp black, as I have already said. Hard fired biscuit is usually accompanied by a flash fire which will retard the escape of the carbon monoxide gases. Some of these will be pushed near the surface on further firing, and will remain in small pockets. I should naturally look for this rather more on the inside of hollow-ware than on the outside. Some of these pockets of gas will be released in the glost oven, facilitated by the action of the glaze. A hard biscuit fire may not of itself cause spit-out, if flash firing is eliminated. The mere introduction of carbon into the biscuit will not cause spit-out. I think Mr. Steele will do well to think again as regards moist atmosphere in warehouses. Slowing down in biscuit firing, if done properly, is good in itself, but Mr. Steele is decidedly mistaken when he says it is a cure for spit-out. I am inclined to think that there are other reasons along with the altered biscuit firing which had not been taken into consideration.

Mr. Steele:—But I have already pointed out that a reduction of the carbon in the body has minimised spit-out. Mr. Moore can give you an instance where a clay that was very high in carbon, when used in the body, caused spit-out, whereas, if this high-carbon clay was eliminated from the body, the percentage of spit-out diminished very considerably.

Mr. Miles:—If you add 5% carbon to your body, avoid flash firing, fire your glost up well, avoid moisture in the glost state, and put it through the enamel kiln, you will not get spit-out.

I cannot argue against what has been Mr. Steele's experience, but if, as I have already said, you intentionally introduce carbon into the body, that is not sufficient to cause spit-out. Dr. Mellor has a sample of carbon spit-out that he intends showing me, but I should be glad if the doctor would prove to me that the moisture was entirely eliminated from the sample in question.

I did not quite catch Mr. Moore's point with regard to the creation of carbon gases in the enamel kiln, and the consequent causing of spit-out. But I may say that I have actually fired up small muffle kilns by accident to 800°, and I have never found spit-out in a thoroughly reducing atmosphere.

MR. MOORE:—No, you would not. It would prevent it.

MR. MILES:—But the ventilation came just below the enamel kiln heat in several cases, and there was no sign of spit-out.

DR. J. W. MELLOR:—It is with mixed feelings that I take part in this discussion. In view of the second paper coming on, I should prefer to say nothing, but I do not think it would be fair to Mr. Miles, or fair to ourselves, to let a number of the statements which have been made go unchallenged. Mr. Miles has located one cause of spit-out, but as Mr. Moore has just pointed out, it was shown many years ago that moisture could produce spitting, and Mr. Moore had such control of it, that he made the spits assume the letter "M". Fortunately the piece was not destroyed, it is before you. In justice to himself and others who have worked on the subject, I think Mr. Miles should have made himself acquainted with what has been public property for many years.

Before we can accept as authoritative Mr. Miles' statement that he does not believe biscuit firing has anything to do with spit-out, I think, *prima facie*, that we are justified in asking for proof that he understands the evidence which has been published on this subject. There is nothing in his remarks to lead one to suppose that he has considered this evidence, and until he has done so, I do not see how his adverse testimony can be of much weight.

His suggested experiment with lamp black has no particular bearing on the point, because there are so many varieties of carbon. Those who have had to do with the burning of carbon from bone ash, the burning of carbon from precipitates, etc., have this brought emphatically before them; again, he cannot get such gross particles as lamp black very intimately associated with the clays. Besides, it is not carbon in the body alone that produces spitting. Among others, carbon spitting requires two conditions:—(i.) the presence of carbon; and (ii.) the access of air at, say, a red heat. Hence, a kiln which has an atmosphere deficient in oxygen while the ware is being heated, and which is more or less quickly cleared at a red heat, is in a favourable condition to produce spitting. If Mr. Miles will vary his experiment as has been done in the specimen I hold in my hand, I think he will convince himself that carbon spitting is very real. The piece in question is a bowl with stilt marks inside; it has contained turpentine; the turpentine has diffused through the stilt marks into the body; the turpentine has been carbonized by heat. Hence the grey colour of the piece. When put through the enamel kiln, the air entering via the stilt marks, has oxidized the carbon as shown by the restored colour of the biscuit, and at the same time spit the glaze.

I wonder what grounds Mr. Miles has for assuming that gases diffuse through capillary pores faster upwards than downwards. Mr. Miles seems to think this makes a marked difference. Does he know Graham's or Fick's work on diffusion? I do not question the

fact that Mr. Miles states, but I do question his interpretation. When he has seriously considered the other side of the subject, he will find that something else is involved. Moisture is one important factor in the spitting of a glaze in the enamel kiln; but it strikes me as a poor hypothesis that requires coddling up with such unwarranted assumptions as: (1) That the pressure of the air inside and outside a jug is different. This statement is enough to make Pascal turn in his grave. (2) That steam (water vapour) expands appreciably more than carbon monoxide or dioxide per unit rise of temperature. Here we might ask: "Have Rankine and Regnault worked in vain?" It is just as easy for me to imagine water of itself running up the hill from Stoke to Hanley, as to imagine Mr. Miles' conditions in opposition to these laws. I put this matter vigorously, because I feel strongly the futility of inventing exceptions to known laws in order to make an hypothesis fit facts. Again I say that I do not question the facts brought forward by Mr. Miles; but I do question his interpretations. Mr. Miles is mixing up at least two distinct and definite causes of spitting. If he will now try and understand the carbon theory, he will find that some of the cases which puzzle him on the moisture theory, fit wonderfully well into the other one. For example, he refers in his paper to a soft flux in the oil producing spit. The oil very probably contained sugar of lead put in as a siccative agent. When this is heated it is carbonized into a form of carbon which is not so easily burnt out. If the fluxes skin over the carbon before it is burnt out, then you have one of the conditions required for carbon spitting. The paper is so interesting and the time so short, that I suggest, Mr. Chairman, that we resume the discussion another evening. We are greatly obliged to Mr. Miles for opening up an important subject. I hope we shall not allow the blemishes in Mr. Miles paper to blind us to the good things which it contains.

Mr. Miles:—I am aware of the publication referred to. As I have already stated there is *no moisture* in an enamel kiln at the spit-out period (*i.e.* 650 to 800°C.) You must bear in mind the *high coefficient of expansion* of superheated steam which *does not contain moisture*—If you impregnate a pottery bowl with pure American turpentine and put it through the enamel kiln the *black colouration* of the sample bowl shown will not happen. Of course, all other deleterious matter must be eliminated, which, in the case of the bowl shown, has almost certainly not been the case. Pascal will not turn in his grave because of any statement that I or any one else makes. That is usually left to other forces of nature. I have not coddled any thing up in my paper, either the theory of difference in pressure inside and outside, say a ewer. My experience tells me it is true. It is for you to disprove the authority on superheated steam expansion. Please tell us how to get that letter M with moisture Let us prove it in practice.

MR. RICHARDSON:—I am sorry that we have to postpone the discussion. Most of the older members of the Society will be aware that there have been many good papers on the subject of spit-out, although there may be many others who are not familiar with them.

I do not think we can quite agree with Mr. Miles' views that superheated steam is the one and only cause of spit-out; I am inclined to think that after this meeting Mr. Miles himself will begin to give his attention to other causes for the fault, which many of us have been familiar with for quite a long time. I believe that to get rid of spit-out we shall have to consider the fault with a very open mind. There are so many difficulties which even now most of those who have followed the subject for many years do not understand and cannot follow through to a conclusion by reasoning. There is yet much to be done on the subject. I cannot think that anyone who really knows how to get rid of spit-out from any and every cause need trouble himself about working any more. But so long as we have spit-out ware there is plenty of room for discussion, and I, personally, shall be very pleased if the discussion can be followed up at another meeting.

I thank Mr. Miles for bringing forward the subject. It is a very thorny problem which we are all extremely anxious to solve, and it can only be solved by constant experiment and discussion.

MR. MILES:—For many years I have given a lot of thought to spit-out and I think you will agree that it is not necessary to advertise the fact in order to prove or disprove that statement. It may be that we shall never get rid of spit-out altogether, even though we keep a very open mind. Nearly all troubles are continued by indecision. Especially does this apply to the process of pottery manufacture. Most of us, I think, would be sorry to have nothing to do. That surely is not the aim and object in life, neither did I propound this theory with that object in view. I agree that it is a thorny problem and that practical experiments will solve it, but I have not the same confidence in a discussion of it.

I thank you all very much for your patience in listening to my reading of this paper. But before I leave the subject for the present, I would advise any of you who are anxious to reduce your spit-out losses: (1) To avoid flash firing in biscuit; (2) To fire your glaze well up in glost; (3) To avoid damp atmosphere and water in the glost warehouses, and (4) To allow no rushing in firing enamel, especially between 650 to 800°C.

XV.—The Reversible Thermal Expansion of Silica.

By H. S. Houldsworth, M.Sc., and J. W. Cobb, C.B.E., B.Sc., F.I.C.

(Fuel Department, The University, Leeds).

THE results of some previous experiments on the reversible thermal expansion of refractory materials have already been described.* Most of them referred to fireclays, or bodies with a fireclay basis, and only preliminary experiments on silica refractories were discussed. It was apparent, however, from these earlier experiments that the observed character of the expansion curves would give indications as to the transformations of silica occurring in silica refractories under the various conditions of heating, apart from other useful information. Accordingly the reversible thermal expansion from 15°C. to 1000°C. was measured for amorphous precipitated silica prepared from silicate of soda and containing some alkali, purer amorphous silica prepared from silicon fluoride, silica glass, ganister (both with and without a lime bond) quartzite, and flint, after preliminary burnings to known temperatures. Generally the test pieces were fired in a works kiln to cone 06 (980°C.) in forty-eight hours or to cone 9 (nominally 1,280°C.) in seventy-two hours before examination. Afterwards the specimens fired to the latter temperature were burned for two hours in a laboratory furnace at cone 14 (1,410°C.) and their expansions again determined. They were then fired at cone 20 (1,530°C.) for two hours and again examined. In this way the changes in expansion due to changes in structure resulting from these preliminary burnings to known temperatures were observed. In addition, wherever it was possible, the substances were examined without any preliminary firing. Unused commercial silica bricks and silica bricks which had been used in coke ovens or steel furnaces were tested so that the effect of burning and of prolonged heating at high temperatures could be studied.

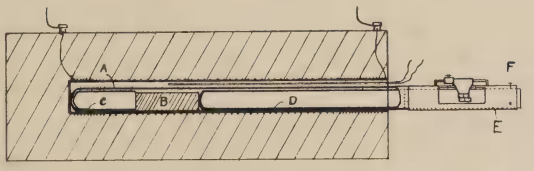


Fig. 1.

In the apparatus used (see Fig. 1), a silica glass (vitreosil) tube heated in an electric furnace had a glass, marked with a fine

* Hodsman & Cobb, *J. Soc. Glass Tec.*, **3**, 201—222, 1919. Houldsworth & Cobb, *J. Soc. Glass Tec.*, **5**, 16—44, 1921.

scratch, attached to the part of the tube which projected from the furnace. The test piece in the form of a rod 20 cms. long, was placed inside the middle length of this tube, the other lengths of which were occupied by two vitreosil distance pieces. The outer distance piece carried on the part outside the furnace a second piece of glass, also marked with a fine line. The relative movement of these fine lines (observed with a microscope fitted with a micrometer eye-piece) gave the expansion of the test piece relative to silica glass, the expansion of which was very small and was accurately known between 15° and 1,000°C. A fuller description of the apparatus and an account of the experimental details, together with a discussion of the experiments performed to test the accuracy of the method, will be found in an earlier paper.*

The porosities of the specimens are given in Table 3 (p. 263.) These were determined by immersing a dried specimen of known weight in paraffin under reduced pressure in a vacuum desiccator for forty-eight hours, then finding its weight suspended in the paraffin, and subsequently weighing the saturated test piece.

$$\text{The porosity} = \frac{\text{weight of paraffin absorbed} \times 100}{\text{loss in weight of saturated test piece on weighing in paraffin.}}$$

It is, therefore, the percentage of the total volume of the test piece occupied by open pores to which paraffin could penetrate.

The true specific gravities of the material are collected in Table 3. For this determination about 3 grms. of the specimen were ground to an impalpable powder, placed in a weighed, dry, specific gravity bottle, and the whole weighed. The bottle was about one-third filled with distilled water, attached to a glass bulb to trap any material ejected from the bottle, suspended in steam, connected with a water pump, and the water in the bottle boiled under reduced pressure for half-an-hour in order to remove all the air entrapped by the powder. The glass trap was washed back into the bottle, which was then placed in a bath of cold water of known temperature, and when cold filled with distilled water at the same temperature and weighed. The bottle was cleaned out and weighed when full of distilled water at the same temperature as that previously used. From these results the weight of water which would occupy the same volume as the powder was obtained. The specific gravities of precipitated amorphous silica containing soda as a flux and of the used silica bricks are also given in Table 3. These were determined by dividing the weight of the test piece by the weight of the paraffin it displaced and multiplying the result by the density of the paraffin. The finely powdered substances immersed in oils of known refractive indices were examined with a petrological microscope. The index of refraction of the cedar wood oil used was 1·503, and it was possible by making use of the Becke

* Hodsman & Cobb, *J. Soc. Glass Tec.*, **3**, 201—222, 1919.

effect to see which particles had an index of refraction greater than that of the oil. Such grains were regarded as quartz or silicates with higher refractive indices. An oil was also prepared with an index of refraction 1·481, a value intermediate between those of cristobalite and quartz. By immersing the material in this oil it was possible to distinguish the cristobalite grains from those of tridymite or silica glass. By immersing the substance in an oil of index of refraction 1·468 the presence of any material with a lower refractive index than tridymite was determined, such particles being regarded as a glass or as amorphous silica. The refractive index was specially useful for tridymite with which the volume change of the α to β transformation is small.

The observed changes in volume, specific gravity, and refractive index accompanying transformations for different forms of silica may be given here. Evidently the detection of a small quantity of tridymite by the expansion on passing from α to β tridymite at 117°C. would be much more difficult than that of cristobalite or quartz.

α–tridymite ⇌ β–tridymite at 117°C. with 0·15 per cent. increase of length.*

α–cristobalite ⇌ β–cristobalite at 220°—280°C. with 1·0 per cent. increase of length.*

α–quartz ⇌ β–quartz at 575°C. with 0·45 per cent. increase of length.*

Density of quartz glass=2·210 (Dana, Endell)
Density of tridymite =2·270 (Fenner)
Density of cristobalite =2·333 (Fenner)
Density of quartz =2·65
Refractive index of α–tridymite =1·469 to 1·473 (Fenner)
Refractive index of α–cristobalite=1·484 to 1·487 (Fenner)
Refractive index of α–quartz =1·544 to 1·533 (Fenner)

The expansion of each of the materials tested will now be considered separately and in detail. The expansions relative to fused silica are shown in figures 2—15. One division in a horizontal direction equals 0·1114 mm.

Amorphous Silica. Although our first experiments in point of time were made with quartzite as being the commonest commercial raw material for silica refractories, we will begin by describing the results obtained with amorphous silica and particularly with amorphous gelatinous silica. This material being devoid of any of the definite orientation of the crystalline forms might be assumed to pass over at any temperature more readily than they into the state corresponding with that temperature. There would be no initial orientation to break down. This point of view necessitated logically a commencement with amorphous silica and the results justified it in our opinion.

* Fenner, *Amer. J. Sci.*, **36**, p. 383, 1913.
Le Chatelier, *La Silice*, Paris, 1914; *Revue Universelle des Mines*, Ser. 5, Vol. I., p. 90(1913).

(*a*) *Precipitated Silica containing soda.* In the course of this investigation it was found that precipitated silica containing a few per cent. of soda was transformed with great ease and rapidity on heating into crystalline forms of silica. Discrepancies in the results observed by different investigators of the stability relations of silica have been attributed to the sluggishness of the reactions studied and to the production of forms of silica which were unstable in the temperature range selected but which, on prolonged heating, would change to the form stable at that particular temperature. A variety of silica which inverted rapidly into other forms of silica on heating obviously possessed advantages in the investigation. The precipitated silica was prepared from commercial water glass which was dissolved in water, filtered, and acidified with hydrochloric acid. The precipitate was washed with water until no turbidity was obtained on testing the washings with silver nitrate. It was hoped to prepare test pieces from the precipitate by simply applying pressure to it, but this was found to be impossible. It was, therefore, dried, and 3 per cent. (by weight) of gelatine was dissolved in warm water and added to the precipitated silica ; the test pieces were then moulded and dried. Precipitated silica prepared in this way according to Le Chatelier† must always contain about 3 per cent. of alkalies, and as prepared by us in considerable quantities actually contained 5 per cent. of soda.

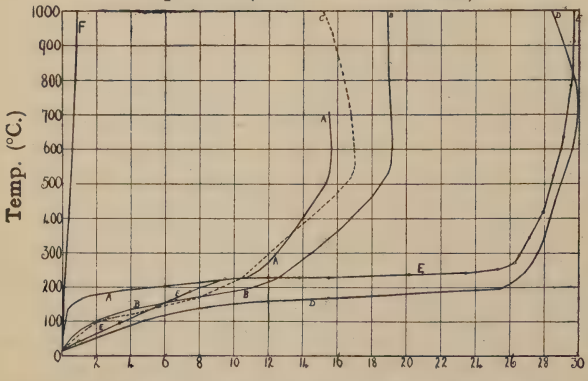


Fig. 2.

A. Precipitated Silica after heating at 700°C for 623¼ hours.

B. Precipitated Silica after heating to 1170°C

C. Precipitated Silica after 5 burns at Cone 9.

D. Silica from Silicon fluoride after heating at 1170°C for 4 hours.

E. Ditto after heating at Cone 14–15 for 2 hours.

F. Vitreosil after heating at 1510–1555°C for 2½-hours.

Precipitated Silica, Heated to 700°C. (see Fig. 2, curve A.) The test piece heated in a muffle to 700°C. cracked badly, so that it was ground up, rebound with gelatine, heated to 700°C. and the gas cut off. On examination in the apparatus the specimen expanded only slightly between 15°C. and 170°C. but from this point to 210°C. a large, rapid, and reversible expansion was noted presumably due to the inversion of α- to β-cristobalite. From 210° to 420°C. the specimen expanded steadily, but from this point to

† Le Chatelier, *La Silice*, p. 30, Paris, 1914.

700°C. a contraction was observed. No evidence of quartz was detected and the results suggested that the precipitated amorphous silica had been converted at any rate partially into cristobalite. The test piece was maintained for two hours at 700°C. in the apparatus before the current was cut off. On reheating, the rapid expansion between 170° and 210°C. was considerably increased being about three times that previously noted and indicated a greater conversion of the amorphous silica into cristobalite. The ease with which the precipitated silica had been converted into cristobalite was remarkable. As the temperature was well within the range in which quartz is regarded as the stable form of silica, it was necessary to investigate the effect of prolonged heating in this range on precipitated silica in order to determine if the cristobalite first produced was an unstable form. Another test piece was heated in a muffle to 790°C. for two hours and examined. The specimen showed an increased rate of expansion about 115° to 120°C. and a much larger coefficient of expansion about 200°C. (Fig. 2). Above 300°C. a little further increase in dimensions took place and after about 470°C. a contraction took place up to 700°C. The expansion at 115°C. to 120°C. occurred at about the temperature at which α–tridymite inverts into β–tridymite with increase of volume. The large expansion at 200°C. would again be explained by the conversion of α–cristobalite into β–cristobalite with the consequent large increase in volume. There was no evidence of the volume changes associated with quartz. It would seem that the amorphous silica had been converted into tridymite and cristobalite by heating for two hours at 790°C. in the presence of about 5 per cent. soda. The test piece was kept in the apparatus for seventy hours at a temperature of 650° to 710°C. The current was then cut off and the furnace allowed to cool. Next day a heating curve was taken and it was found that the increase in length at 200°C. was greater than before, while the change at 115°C. was not very noticeable, suggesting that the small amount of tridymite at first formed had been converted into cristobalite. Again there was no expansion between 500° and 700°C., and therefore no evidence of the presence of quartz. The test piece was maintained in the apparatus for a further ninety-one-and-a-half hours at 680°C. to 720°C. and the furnace then allowed to cool. The increase in length at 200° to 250°C. on heating up the specimen was again greater than in the previous determination, while there was still no expansion above 500°C. After this in a number of successive heatings the character of the expansion curve remained the same but the expansion about 200°C. gradually diminished until finality (and presumably the stable condition) was very nearly attained after 768 hours heating.

The specimen now showed a rapid expansion between 150°C. and 250°C. (Fig. 2, curve A), which suggested that this long heating at 700°C. had produced cristobalite, and not the quartz which

would have been expected at this temperature according to the stability ranges as stated by Fenner. There was no evidence at all of the presence of quartz nor of the small amount of tridymite which was probably produced at first along with cristobalite. It was found that almost all the particles had a refractive index greater than 1·481 and less than 1·503 and were therefore cristobalite. None of them possessed a refractive index greater than 1·503 so the quartz was completely absent. A few grains had a refractive index less than 1·481 but greater than 1·468 and were regarded as tridymite while the few particles of refractive index less than 1·468 were considered to be unchanged amorphous silica. Microscopic examination thus confirmed the deduction from the expansion test that the amorphous precipitated silica had been converted into cristobalite at 700°C, but that it was associated with very small amounts of tridymite and unchanged amorphous silica.

Precipitated Silica heated to 1,150° *to* 1,170°C. (Fig. 2, curve B). The precipitated silica was bound with gelatine and heated to 1,170°C. in a laboratory furnace. The test piece cracked and so was ground up, again bound with gelatine, and reheated to 1,170°C. It was then examined in the apparatus. The character of the expansion temperature graph was different from that obtained for the specimen burned at 700°C. The test piece expanded steadily to 100°C. but the rate of expansion was considerably increased from 100° to 200°C. the expansion in this range being five times that from 15° to 100°C. The rate of expansion again decreased above 200°C. and from this temperature to 550°C. the coefficient of expansion was nearly the same as from 15° to 100°C. At about 550°C. the expansion ceased abruptly, and from this point to 1,000°C. a slight contraction was observed. On cooling the more rapid expansion between 100° and 200°C. was reversible. The expansion curve suggested that tridymite was present in quantity.

Precipitated Silica burned five times to cone 9 *in a works kiln.* (Fig. 2, curve C.). In order to test the effect of prolonged heating at 1,150° to 1,170°C. on precipitated silica a test piece was prepared from the material previously heated to 790°C. for two hours and which was mainly cristobalite. It was then submitted to five burns in a works kiln at cone 9, to a maximum temperature of 1,170°C. as recorded by a thermocouple. A large expansion was observed between 100° and 170°C. after which there was a fairly large but regular expansion to 550°C. followed by a contraction from this temperature to 1,000°C. The cooling curve was similar to the heating curve. The large discontinuity in expansion occurring between 100° and 170°C. would seem to be attributable to the α – to β – tridymite transformations rather than to those associated with cristobalite. No quartz was detected and it seemed probable that the cristobalite resulting from the calcination of the amorphous silica at 790°C. had been converted largely into

tridymite by prolonged heating at 1,170°C. The expansion was similar to that observed for the precipitated silica fired just to 1,170°C. in the laboratory, although in the latter test piece the actual expansion from 100° to 200°C. was greater than in the former. The powdered material was examined with the microscope. No quartz could be detected, the whole of the sample examined having an index of refraction less than 1·503. Some of the material had a refractive index greater than, and some less than, 1·481, so that it would appear to be a mixture of tridymite and cristobalite, the tridymite being at least half of the specimen. No unconverted amorphous silica could be detected. The specific gravity of the material was 2·28 which would correspond with a test piece which was largely tridymite.

Precipitated Silica burned at cone 14—15 *for two hours.* The specimen previously burned at cone 9 was next heated in a gas-fired laboratory furnace for two hours at cone 14—15, and its expansion from 15° to 1,000°C. again determined. The behaviour of the test piece was not very different from that obtained for the precipitated silica after firing just to 1,170°C. in the laboratory. Microscopic examination showed the material to be very similar to that obtained after firing to 1,170°C. Quartz was entirely absent as was also unchanged amorphous silica for practically all the material had an index of refraction greater than 1·470. The sample again appeared to consist of tridymite and cristobalite in roughly equal amounts.

(*b*) *Pure Amorphous Silica. Silica prepared from Silicon Fluoride.* A mixture of sand and fluorspar was heated with concentrated sulphuric acid in a lead flask and the resulting silicon fluoride gas bubbled through a crucible containing mercury immersed in a dish of distilled water, when hydrofluo-silicic and silicic acid were produced.

$$3SiF_4+3H_2O=2H_2SiF_6+SiO_2\cdot H_2O$$

The supernatant liquid was decanted and the product washed several times by decantation with distilled water and finally dried, when pure silica was obtained. Test pieces were prepared by binding the silica with gelatine, not more than 0·18 per cent. of impurity (ash) being introduced thereby.

Pure Amorphous Silica heated to 700°C. The test piece was heated in a muffle to 700°C. and the gas then cut off. On examination no expansion or contraction was observed on heating the specimen from 15° to 700°C. in the apparatus so that its expansion must be the same as that of the silica glass (vitreosil) tubes. The temperature of the furnace was maintained about 630°C. for seventy-two hours and the current then cut off. No expansion or contraction was noted on reheating the specimen to 700°C. in the apparatus. The furnace was next kept at 700°C.$\pm$10° for twenty-six hours and the test piece re-examined after cooling. Again no expansion or contraction was detected, showing that heating

to 700°C. did not transform the pure amorphous silica into any of the crystalline forms of silica, a result in strong contrast to that obtained for amorphous silica containing soda.

Pure Amorphous Silica heated to 1,150° *to* 1,170°C. (Fig. 2, curve D.) The specimen was next fired to 1,150° to 1,170°C. for four hours in a gas fired laboratory furnace and examined. Its rate of expansion from 15° to 150°C. was large and was succeeded by an extremely large expansion between 150° and 240°C. the temperature expansion graph being practically paralled to the expansion axis. From 240° to 500°C. the test piece expanded slightly, while above 500°C. little further expansion took place, and from 650° to 1,000°C. a slight contraction was observed. The extremely large expansion from 170° to 240°C. was reversible on cooling and must be attributed to the large volume change associated with the conversion of α to β cristobalite. No evidence of the presence of tridymite or quartz was obtained from the expansion of the specimen.

Microscopic examination showed that the refractive index of the whole sample was less than 1·503 confirming the absence of quartz. About half of the material examined had a refractive index greater than 1·481 and was cristobalite. The index of refraction of a considerable portion of the remainder was less than 1·468, corresponding with unaltered amorphous silica, and that of another portion lay between 1·481 and 1·468 corresponding with tridymite. The specimen was, therefore, taken to consist of cristobalite associated with unaltered amorphous silica and a little tridymite not detected by the expansion test.

Pure Amorphous Silica heated to cone 14—15 (1,410° to 1,430°C.). (Fig. 2, curve E.). A test piece prepared from the pure amorphous silica was heated in a gas-fired laboratory furnace for two hours at cone 14—15 prior to examination. The expansion temperature graph obtained for this sample was almost identical with that given by the specimen fired to 1,170°C. showing that the bulk of the material was again cristobalite.

Silica Glass. Ordinary commercial samples of vitreosil were used for these experiments so that they would have been prepared from silica in a pasty condition rather than from completely fused silica. Before this investigation was attempted the accuracy of the method had been tested by inserting a vitreosil distance piece in the apparatus in the position usually occupied by the specimen. Practically no change in its dimensions could be detected, with the exception of a very slight contraction above 800°C. After the apparatus had been used for about eighteen months, during which time it had been repeatedly heated to 1,000°C., a further test was made by again replacing the specimen by the vitreosil distance piece. No change in the dimensions of the latter could be detected with the exception of the very slight and practically negligible contraction between 800° and 1,000°C. This result

showed that no appreciable change had been produced in the vitreosil tubes of which the apparatus was constructed by repeated heatings to 1,000°C.

Vitreosil after heating to 1,150° *to* 1,170°C. *for four hours.* A vitreosil distance piece was heated in a gas-fired laboratory furnace to 1,150° to 1,170°C. for four hours and examined. After cooling no expansion could be detected from 15° to 800°C. but the slight contraction from 800° to 1,000°C. was again noted. Nearly the whole of the powdered unused vitreosil had a refractive index less than 1·468. After heating to 1,170°C. the bulk still had a refractive index less than 1·468 showing that it had not been converted into the crystalline forms of silica by this treatment.

Vitreosil after heating to cone 14—15 *for three hours.* On examining the vitreosil distance piece after it had been burned to cone 14—15 for three hours, the results obtained were the same as after firing to 1,170°C. no measurable change in its thermal expansion having been produced. The refractive indices of the powdered material showed that the greater part of it had an index of refraction less than 1·468. The refractive index of the rest was between 1·481 and 1·468 and was taken to be tridymite. A few particles only had a refractive index greater than 1·481 but less than 1·503. The refractive indices therefore indicated unaltered glass and some tridymite with a few crystals of cristobalite.

Vitreosil after heating to 1,510° *to* 1,555°C. *for* $2\frac{1}{2}$ *hours.* (Fig. 2, curve F.). A distance piece of vitreosil was tested after heating to 1,510° to 1,555°C. for $2\frac{1}{2}$ hours. It showed no change of dimensions to 200°C. but from this temperature it expanded slightly but steadily to 1,000°C. the actual expansion being about ·05 per cent. Microscopic examination showed that the whole of the material had an index of refraction less than 1·481 so that both quartz and cristobalite were absent. About one-third to one-half of the material had a refractive index greater than 1·468. The sample therefore consisted according to refractive indices of a mixture of tridymite and unchanged vitreosil.

Summarising, the experiments showed that little change took place in the vitreosil tubes by repeated heatings to 1,000°C. or by four hours burning at 1,150° to 1,170°C. After firing for three hours to cone 14 some tridymite appeared while heating for $2\frac{1}{2}$ hours at 1,510° to 1,555°C. resulted in from 30 to 50 per cent. of the vitreosil being transformed into tridymite according to the indications of refractive index. In all our other experiments cristobalite had been the form of silica produced in quantity at high temperatures but it must be remembered that the tridymite obtained in this case may be an unstable form. The vitreosil was not in the form of a powder and consequently might not be transformed as readily as finely divided substances. Rieke and Endell* found that when powdered quartz glass was heated at

* K. Endell & R. Rieke, *Z. angew. Chem.*, **25**, pp. 2019—2020, 1912.

1,400°C. for two hours 25 per cent. of it was converted into cristobalite, while two hours burning at 1,500°C. transformed the whole of it into cristobalite.

The effect of fluxes in facilitating the transformation of amorphous into crystalline silica was clearly seen in our experiments. In the presence of 5 per cent. of soda heating at 700°C. for two hours was sufficient to transform the amorphous silica almost completely into cristobalite, although pure silica prepared from silicon fluoride and vitreosil were unaltered by similar treatment. The cristobalite produced at 700°C. from amorphous silica in the presence of soda was changed largely into tridymite by heating to 1,170°C. or to cone 14. On the other hand, cristobalite was the chief product obtained by heating pure amorphous silica prepared from silicon fluoride to the corresponding temperatures. Vitreosil was not changed after firing for 2½ hours to 1,170°C. but some tridymite was present after heating to cone 14 and still more was present after heating to 1,510 to 1,555°C.

The transformation of the cristobalite first obtained by heating precipitated silica in the presence of soda to 790°C. into tridymite on heating at 1,170°C. gave support to Fenner's view that tridymite is the most stable form of silica at the latter temperature.

The non-production of quartz was remarkable in view of its wide distribution and the very rare occurrence of cristobalite and tridymite in nature. The density of quartz is higher than that of the other crystalline forms of silica and it may be that pressure as well as appropriate heat treatment would facilitate its formation.

It is our intention later to investigate the effect of heating powdered silica glass, pure amorphous silica and quartz to which various fluxes have been added. The difficulty of producing quartz from other forms of silica was mentioned above. We hope to study the influence of innoculating the precipitated silica before firing with fine quartzite or flint flour. Some ordinary raw materials for silica refractories were next examined.

Expansion (1 div. = 0·1114 mm.)

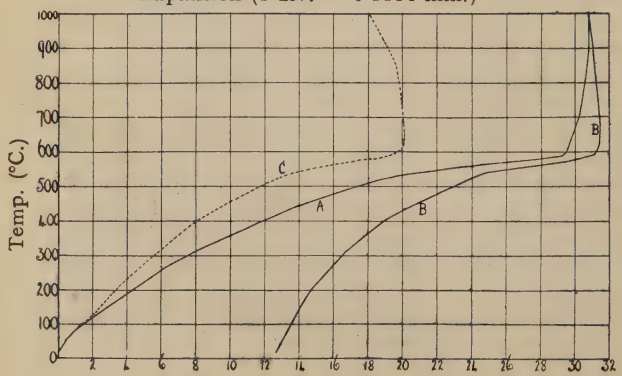


Fig. 3

MEANWOOD GANISTER WITHOUT BOND.

A. 1st heating

B. 1st cooling

C. 2nd heating

Meanwood Ganister without bond. (Fig. 3). A test piece was cut from a block of Meanwood ganister as quarried and its expansion measured. On heating for the first time the specimen had a very large expansion from 15°C. to 500°C. and did not exhibit any marked discontinuity in this range. From 500° to 600°C. the rate of expansion was still greater, due to the increase in volume associated with the inversion of α–quartz into β–quartz at 575°C. A marked change in the character of the temperature-expansion graph was observed at 600°C. From this point to 900°C. the coefficient of expansion of the ganister was small, and this expansion was followed by a slight contraction from 900° to 1,000°C. On cooling, the ganister expanded slightly from 1,000 to 600°C. From 600° to 550°C. a very rapid and large contraction took place which would be explained by the conversion of β– into α–quartz. On cooling through the rest of the range, the test piece contracted steadily, the coefficient of contraction decreasing with decreasing temperature. It was found that the heating of the ganister in this way had resulted in a permanent linear expansion of 0·7 per cent. The very large expansion observed on the first heating was the sum of this permanent increase in length and the reversible thermal expansion of the test piece. The ganister was then reheated and the character of the temperature-expansion graph was the same from 15° to 600°C. as that obtained for the first heating, although the actual expansion was only about two-thirds of that previously observed. From 600° to 1,000°C. the specimen contracted slightly but steadily. The cooling curve did not differ appreciably from the heating curve but from 400°C. to 15°C. the contraction was less than the expansion had been in this range, so that the test piece showed a further permanent linear expansion of 0·08 per cent. No marked discontinuities in the expansion-temperature curve were noted at 100°C., or at 200°C. to 280°C., such as would be observed if tridymite or cristobalite were present in appreciable amount, so that it seemed that the large permanent expansion obtained on the first heating of the ganister could not be ascribed to the transformation of quartz into tridymite or cristobalite and that some other explanation must be sought. It should also be noted that on the first heating the specimen expanded from 600° to 900°C. while subsequently a contraction was always observed in this range on heating and an expansion on cooling. It would seem that an expansion of a permanent character was taking place from 600°C. on the first heating and that this more than counterbalanced the contraction of the β quartz which we had always noted from 600° to 1,000°C. This range (600° to 900°C.) was below the temperatures given by Fenner for the inversion point of quartz into tridymite or cristobalite which also suggested that the permanent expansion of the ganister was not due to allotropic transformations of the quartz. The true specific gravity of the raw ganister was 2·65 and changed after three heatings to 1,000°C. in the

apparatus to 2·64 indicating that very little or no transformation of the quartz had taken place. The porosity of the ganister had, however, changed considerably on heating in the apparatus being 17·0 per cent. after heating compared with 14·4 per cent. for the raw ganister, a difference which is more than sufficient to account for the observed increase in length. The large difference in the expansion of the ganister on the first and second heatings was about the same as the difference between the permanent expansion on the two heatings and undoubtedly was to be attributed to this cause. The third heating curve was almost the same as that for the second heating, the actual expansion to 1,000°C. being slightly less than on the previous heating. A very slight permanent expansion was noted after the third heating (0·01 per cent. of the original length). The increase in dimensions of the ganister on heating to 1,000°C., was then due to an increase of porosity resulting presumably from a re-arrangement of the quartz particles. It is important to makers and users of all bricks made from quartzitic material.

Expansion (1 div. = 0·1114 mm.)

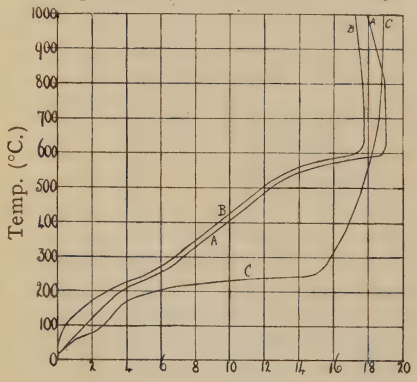


Fig. 4.

MEANWOOD GANISTER WITHOUT BOND.

A. After 6 burns at Cone 9.

B. After further heating for 2 hours at Cone 14.

C. After further heating for 2 hours at 1530—1555°C.

Meanwood Ganister burned repeatedly at cone 9. (*Fig.* 4). A sound block of Meanwood ganister was cut approximately to brick size and measurements were taken by means of callipers placed across smooth and parallel facets ground on the rock. It was fired repeatedly in a works kiln to cone 9 (1,170°C. as measured by a thermocouple) until no further expansion could be detected. Changes in size were noted after each burn and the results obtained are given in the following table.

TABLE I.

EXPANSION OF BLOCK OF MEANWOOD GANISTER AFTER FIRING REPEATEDLY TO CONE 9.

Mark	Original length	After heating in kiln for						Total Expansion
		1 burn	2 burns	3 burns	4 burns	5 burns	6 burns	
I.	20·7 cms.	20·9	20·9	21·0	21·1	21·1	21·1	0·4 cms.
II.	20·5 cms.	20·7	20·8	20·9	20·9	20·9	20·9	0·4 cms.
Width	11·3 cms.	11·4	11·5	11·5	11·6	11·55	11·55	0·25 cms.

Average permanent expansion = 1·92%

It will be seen that the average increase in length was 1·92 per cent. If the whole of this increase in length were caused by the allotropic transformation of quartz it would require 42 per cent. of the quartz to be converted into cristobalite, or 34 per cent. of the quartz to be transformed into tridymite which would require the real specific gravity to be 2·51. Actually the specific gravity was 2·59 which would correspond with a mixture of 83 per cent. quartz and 17 per cent. cristobalite, or of 86 per cent. quartz and 14 per cent. tridymite so that less than half of the permanent expansion after firing repeatedly to cone 9 was due to conversion of the quartz into cristobalite or tridymite. The other part of the permanent expansion must be attributed to an increase of porosity. Unfortunately the porosity of this ganister before firing was not determined so that no numerical check could be made.

A specimen was then cut off from this block and examined in the apparatus. From 15° to 550°C. it expanded regularly, except that it showed a somewhat larger rate of expansion between 200° and 250°C. than was observed in the other parts of the range. Between 550° and 600°C. there was a very rapid and large expansion, the temperature-expansion graph becoming almost parallel to the abscissa along which the expansions were plotted. About 600°C. the expansion of the specimen ceased and from this point to 1,000°C. a slight contraction was observed. On cooling the temperature expansion graph very nearly coincided with the heating curve, the more rapid expansions between 550° and 600°C. and between 200° and 250°C. being reversible. Accepting the volume transformations ascribed to tridymite, cristobalite, and quartz, the slight increase in the coefficient of expansion between 200° and 250°C. would be attributed to the inversion of the α–cristobalite in the specimen to β–cristobalite, and in view of the large increase of volume which is associated with this inversion of cristobalite it was evident that the test piece contained only a small percentage of cristobalite. The rapid reversible expansion between 550° and 600°C. was caused by the inversion of α–quartz into β–quartz and the large expansion noted in this range showed that the bulk of the specimen was quartz. These conclusions were supported by the density of the ganister which was 2·59, that is very little lower than that for quartz, and which corresponded with 83 per cent. quartz, and 17 per cent. cristobalite, or to 86 per cent. quartz and 14 per cent. tridymite. Microscopic examination showed that the index of refraction of the bulk of the material was greater than 1·503 and that no material was present with an index of refraction less than 1·481, showing that the specimen was mostly quartz associated with a little cristobalite. Thus all the tests agreed in showing that the specimen was very largely quartz after this prolonged heating at cone 9.

Meanwood Ganister fired at cone 14. (Fig. 4). The specimen was again examined after further heating for two hours at cone

14 (1,410°C.) Its expansion now varied only slightly from that obtained previously while its true specific gravity had been reduced very slightly. A little greater expansion was noted between 200° and 250°C. and a slightly smaller expansion between 550° and 600°C. This would indicate that the higher burning had converted a further small amount of quartz into cristobalite, a result which was confirmed by a slight reduction in the specific gravity. Microscopic examination showed that the bulk of the material had an index of refraction greater than 1·503 and that all had an index of refraction greater than 1·481, thus confirming that the specimen consisted of quartz with a small amount of cristobalite. It was of interest to note that very little of the quartz had been converted into cristobalite and none into tridymite by prolonged heating at cone 9 (actually 1,170°C.) or further heating for two hours at cone 14 (1,410°C.) although these temperatures were well above 870°C., the temperature given by Fenner for the inversion of quartz into tridymite.*

After heating to 1,530° *to* 1,555°C. (Fig. 4) The same test piece was heated for two hours in a gas fired furnace at 1,530° to 1,555°C. as determined by the Holborn-Kurlbaum pyrometer. On examination in the apparatus the expansion of the material then showed a marked change. The test piece expanded regularly to 200°C. but from there to 250°C. a very large and reversible expansion took place. From 250° to 700°C. the coefficient of expansion was regular but small, and was exceedingly small from 700° to 1,000°C. The rapid expansion previously observed from 550° to 600°C. had been completely removed. These results corresponded with the practically complete conversion of the quartz into cristobalite, with the consequent substitution of a large and reversible expansion between 200°C. and 250°C. for the previously observed rapid, reversible expansion between 550° and 600°C.

These conclusions were confirmed by the specific gravity of the material which had become 2·325 which would correspond with 92 per cent. cristobalite and 8 per cent. tridymite. Microscopic examination of the powdered specimen showed the complete absence of quartz. The greater part of the material had an index of refraction greater than 1·481 and less than 1·503, and was therefore cristobalite, but was associated with a fair amount of material of refractive index less than 1·481, and therefore probably tridymite.

Summarising, it was found that burning Meanwood ganister without bond to cone 9 repeatedly or subsequently heating to cone 14 for two hours caused a small part only of the quartz to be converted into cristobalite and that tridymite was not produced at all. On firing to cone 20 for two hours, however, the whole of the quartz was transformed into the lower density modifications of silica, cristobalite being in very large excess of the tridymite produced.

Meanwood Ganister with lime bond. Meanwood ganister was

* 870° C. quartz $\rightleftharpoons$ tridymite. 1470°C. tridymite $\rightleftharpoons$ cristobalite. (Fenner, *op. cit.*)

ground, sieved through a 25 mesh standard (I.M.M.) sieve, mixed with 3 per cent. plaster of Paris added as slip, moulded and dried.

Unfired Material. An unfired test piece was heated to 1,000°C. in the apparatus. The expansion was large up to 500°C. but a much greater rate of expansion was observed between 500° and 600°C. Only a slight expansion took place between 600° and 800°C., while from 800° to 1,000°C. a slight contraction was noted. As before the rapid expansion between 550° and 600°C. was considered due to the inversion of α– quartz into β–quartz with the accompanying increase in volume. On cooling little change of dimensions was observed until 600°C. but from this temperature to 550°C. a rapid and large contraction was noted (though not nearly so large as that shown on heating). From 550° to 15°C. the coefficient of contraction decreased as the temperature diminished. When cold the specimen was found to have undergone a permanent expansion of about 0·6 per cent. The expansion observed on heating for the first time to 1,000°C. was made up of the reversible thermal expansion of the substance together with the permanent expansion caused by the heating. The pronounced effect of the permanent changes on the expansion during the first heating of the ganister was shown by the coefficients of expansion obtained, which, on heating the specimen a second time in the apparatus, were from 15° to 500°C. $1{,}011 \times 10^{-8}$, 500° to 600°C, $2{,}724 \times 10^{-8}$, 600° to 1,000°C. 29×10^{-8} compared with $1{,}416 \times 10^{-8}$. $5{,}731 \times 10^{-8}$, and 92×10^{-8} for the three temperature ranges respectively for the first heating. A permanent expansion of 0·03 per cent. occurred after the second and third heatings. The expansion on heating for the third time was less than for the second heating, but the change was very small, owing to the much smaller additional permanent expansion. The expansion temperature graphs obtained were similar to those obtained for the ganister without bond (figure 3). The differences between the successive heating curves were almost the same as the differences between the corresponding permanent expansions. In view of the results described for the same ganister fired for a much longer period to cone 9 in a works kiln, it does not seem possible to ascribe these changes to the formation of tridymite or cristobalite while the specimen was above 870°C. The porosity had increased by about $4\frac{1}{2}$ per cent. as a result of the heating and would account for the permanent change in dimensions without any conversion of the quartz. A further test on this point was carried out. A fresh sample was taken and a heating and cooling curve determined, the maximum temperature to which the material was heated being, however, only 674°C. A permanent expansion of 0·16 per cent. resulted and on reheating a decrease in the coefficient of expansion was found and was again roughly the same as the amount of the permanent expansion (Fig. 5). After heating at so low a temperature, this decrease in expansion between 500° and 600°C.

could hardly be considered due to transformation into cristobalite and tridymite. The maximum temperature was below the range for either according to Fenner.

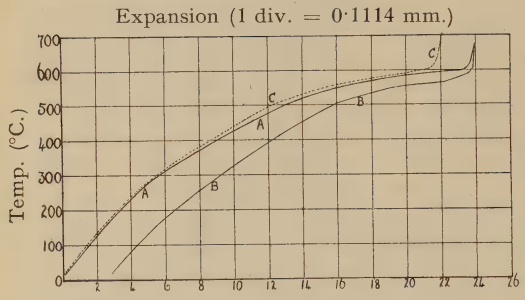


Fig. 5.

MEANWOOD GANISTER WITH BOND (UNFIRED).

A. 1st heating to 674°C.
B. 1st cooling.
C. 2nd heating.

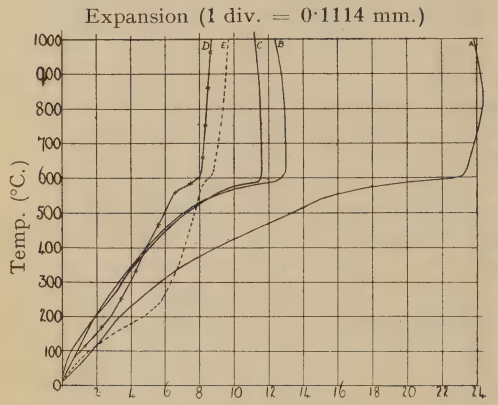


Fig. 6.

MEANWOOD GANISTER WITH LIME BOND.

A. Unfired.
B. Burned at Cone 06.
C. ,, ,, ,, 9.
D. Heated for 2 hours at Cone 14.
E. ,, ,, ,, ,, 19.

Cone 06. (Fig. 6). A sample which had been prepared with the unfired test piece but had been fired subsequently to cone 06 in a works kiln in forty-eight hours showed a much smaller expansion between 15° and 500°C. the increase in length in this range being little more than one-half of that observed for the unfired material. From 550° to 600°C. the large and rapid expansion characteristic of quartz was noted, but was only about 50 per cent. of that given by the unfired specimen, although there was no sudden expansion at about 100° or 200°C. such as would be expected if tridymite or cristobalite were present in quantity. From 600° to 1,000°C. a slight contraction took place. The curve was very similar to the one obtained on heating a test piece made from unfired ganister and 3 per cent. plaster and which had been heated once previously in the apparatus to 1,000°C. The absence of the expansions associated with tridymite or cristobalite was confirmed by the specific gravity which was 2·63. Microscopic examination showed that all the material had a refractive index greater than 1·481, indicating the absence of tridymite, and that the index of refraction of prac-

tically all the substance was greater than 1·503, showing that little or no quartz had been transformed by firing to cone 06.

Cone 9. (Fig. 6). The curve obtained with a test piece burned in a works kiln to cone 9 in seventy-two hours was very similar to that obtained for the sample fired to cone 06, except that the expansion was not so great between 550° and 600°C.; again, no expansion about 120° or 200° to 250°C., indicative of tridymite or cristobalite was obtained. The specific gravity of the material was now 2·60, which confirmed the almost complete absence of tridymite and cristobalite. Microscopic examination also showed that the test piece consisted of quartz associated with a very small amount of cristobalite for the index of refraction of the particles examined were all greater than 1·481, and nearly all greater than 1·503. It would seem that the heating of Meanwood ganister with plaster bond to successively higher temperatures up to cone 9, resulted in a decreased expansion between 550° and 600°C. without the appearance of other expansions such as would indicate that quartz had been converted into tridymite or cristobalite.

Cone 15. (Fig. 6). The test piece previously fired to cone 9 in the works kiln was next heated for two hours at cone 15 in a gas-fired laboratory furnace, and its expansion again determined. It will be seen from Figure 6 that the second heating curve now showed a smaller expansion from 15° to 550°C. and a considerably smaller expansion between 550° and 600°C. than was observed with the cone 9 test piece. A slight expansion took place from 600° to 1,000°C. instead of the contraction previously noted in this range. A slightly greater expansion was observed between 100° to 250°C. which would be explained by the inversion of a little of the quartz into cristobalite. The specific gravity was 2·49 which would correspond with 53 per cent. quartz and 47 per cent. cristobalite. The refractive index of the material examined was all greater than 1·481 and a large part greater than 1·503. Microscopic examination, therefore, showed that the specimen was a mixture of quartz and cristobalite with quartz in excess.

Cone 19. (Fig. 6). The sample which had been fired to cone 15 for two hours was then burned for a further two hours at cone 19. The changes noted after heating to cone 15 were further intensified. The expansion on second heating from 100° to 250°C. had been almost doubled; from 250° to 550°C. the coefficient of expansion was small but regular; the discontinuity from 550° to 600°C. was slight, and from 600° to 1,000°C. the expansion was small but fairly regular. The cooling curve was similar to the heating curve. On the usually accepted theories of the transformations of silica these results indicated that the quartz had been converted largely into tridymite and cristobalite. It would seem that the expansion of these forms of silica above 600°C. more than compensated for the contraction of the β–quartz on heating in this range.. The forms of the curves so far obtained would suggest that the heating

from cone 15 to cone 19 brought about a rapid conversion of ganister to cristobalite and not tridymite, but that with ganister and plaster, tridymite may be formed in some quantity along with cristobalite.

It will have been noticed that the curves shown for the test pieces fired to cones 15 and 19 in the case of the ganister with plaster bond have been the second heating curves. It was found that the second heating curves for these particular test pieces differed considerably from the first heating curves between 15° and 250°C. as will be seen from Figure 7. The α to β–tridymite or cristobalite inversions were not exhibited much on the first heating,

MEANWOOD GANISTER WITH LIME BOND AFTER HEATING FOR 2 HOURS AT CONE 19.

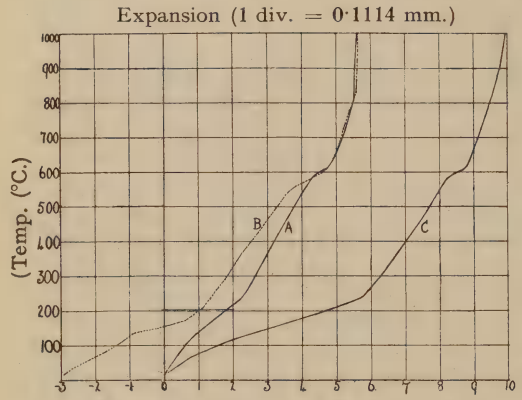


Fig. 7.

A. 1st heating.

B. 1st cooling.

C. 2nd heating.

though clearly seen on cooling or on subsequent heatings. This phenomenon is important and has been observed repeatedly. A suggested explanation is that owing to the rapid cooling which took place when the gas was shut off from the laboratory furnace in which the specimens were burned preliminary to examination, the crystals of α cristobalite or α tridymite did not form. During the first slow heating the α to β cristobalite or tridymite inversion with corresponding expansion would not occur but it would always occur afterwards. Or it may be that quartz in the process of conversion to cristobalite or tridymite, first passes into an amorphous form which only yields crystalline cristobalite or tridymite on such prolonged thermal treatment as that of a slow heating.

It has been shown that ganister without an added bonding material and burned to 1,500° to 1,550°C. showed on testing a large reversible and rapid expansion between 200°C. and 250°C. due to the cristobalite inversion. This large expansion was observed on the first heating and was not increased on subsequent heatings. This difference in behaviour would suggest that the bond material was responsible for the delay in the expansion effect and in the formation of the cristobalite crystals responsible for the effect.

The difference between the heating and cooling curves of the ganister bound with plaster and fired to cone 06 or to cone 9 was remarkable. In each case the change in dimensions between 500° and 600°C. was greater on cooling than on heating (see Fig. 8).

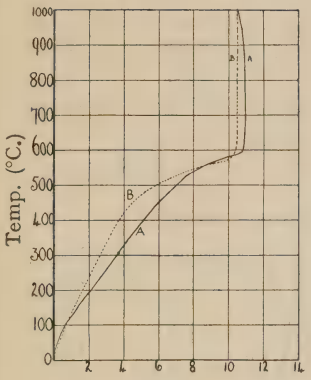


Fig. 8.

MEANWOOD GANISTER WITH BOND AFTER HEATING AT CONE 9

A. 2nd heating.

B. 2nd cooling.

This did not apply in the case of the test piece cut from the block of ganister burned repeatedly at cone 9, for here the heating and cooling curves practically coincided. A similar difference between heating and cooling curves was noticed in the case of fireclays containing free quartz. The condition with fireclays was analogous to that of ganister bound with lime, for in both cases fluxes were present with the quartz. The transformations from $\alpha - \beta$ quartz are apparently not strictly reversible changes in mechanical structure. But since very little permanent change was noted in the dimensions of the specimens after heating in the apparatus the particles presumably regained very nearly their original positions on cooling to air temperature.

It was also noticed that the coefficient of expansion of the ganister decreased slightly with subsequent heating in the apparatus. The coefficients of expansion from 15°C. to 1,000°C. for the sample burnt to cone 9 were 683×10^{-8} for the first heating, 646×10^{-8} for the second heating, and 596×10^{-8} for the third heating. Similar results were noted for the test pieces burnt to other temperatures before testing. In view of the progressive decrease in reversible thermal expansion after firing the samples to cone 06 and cone 9, this cannot be attributed to the conversion of the quartz into cristobalite and tridymite, for with these specimens large changes in the expansions observed between 500° and 600°C. were apparently unaccompanied by appreciable inversion of quartz to tridymite or cristobalite. It is probably due to a disturbance in the orientation and grouping of the quartz crystals consequent upon the double inversion and volume change of each experiment.

We may recall that fireclays fired to cone 06 or cone 9 showed a

slightly increased expansion on repeated heatings in the apparatus. This effect is in the opposite sense but a similar explanation is not excluded.

Quartzite. It was considered desirable to repeat the preceding set of experiments with some other raw materials commonly used in the production of silica brick and a Welsh (Bwlchgwyn) quartzite was selected for this purpose. It was ground and sieved through a 20-mesh standard I.M.M. sieve, 3 per cent. plaster added as slip, moulded into shape, and dried.

(*a*) *Unfired.* (see Fig. 9). The expansion temperature

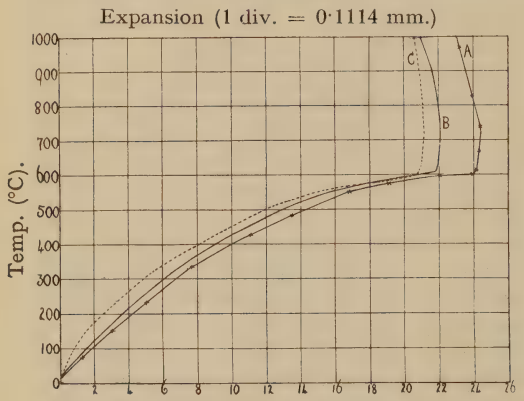


Fig. 9.

Welsh Quartzite with Bond (unfired).

A. 1st heating.

B. 2nd heating.

C. 3rd heating.

curve obtained for the unfired test piece was very similar to that given by the unfired ganister bound similarly with plaster. The cooling curve was nearly the same as the heating curve, and the expansion observed on reheating was only slightly less than that obtained on the first heating, results in marked contrast to those obtained with Meanwood ganister. The permanent expansion as a result of the first heating was only 0·09 per cent. compared with 0·6 per cent. in the case of ganister. (Since the expansion on the first heating was always made up of both the true thermal expansion and the permanent expansion, less difference would be expected between first and second heating curves for a substance showing only a small permanent increase in dimensions as a result of heating than for one giving a large permanent expansion. A further slight permanent expansion (0·03 per cent.) occurred after the second heating, and the expansion on heating for a third time was slightly less than that obtained on the second heating, the difference between the second and third heating curves being less than that for the first and second heatings. The reversible thermal expansion of this quartzite from 15° to 1,000°C. was greater than that given by Meanwood ganister.

(*b*) *Cone* 06. (Fig. 10, curve B.). The expansion for the test piece which had been fired to cone 06 in a works kiln was almost

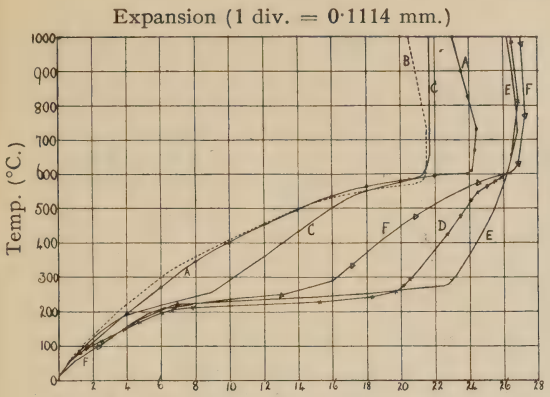


Fig. 10.

WELSH QUARTZITE WITH BOND.

A. Unfired.
B. Burned at Cone 06.
C. ,, ,, ,, 9.
D. Heated for 2 hrs. at Cone 14.
E. Ditto at 1510—1550°C.
F. Quartzite Flour burned at Cone 9.

identical with that obtained for the second heating of the unfired specimen, *i.e.*, no irregularity in the curve could be detected at 110°C. or 200° to 280°C. such as would be associated with tridymite or cristobalite, but a large expansion took place between 500° and 600°C. due to the α- to β-quartz inversion. The specific gravity of the material was 2·63, compared with 2·64 for the unfired quartzite. The whole of the material had an index of refraction greater than 1·503 so that it was unconverted quartz.

(*c*) *Cone* 9. (Fig. 10, curve C.). The temperature expansion curve for the quartzite burned to cone 9 in a works kiln was very different. The test piece expanded steadily to 150°C. but from this temperature to 250°C. a much greater rate of expansion was noted. From 250° to 550°C. the rate of expansion was again smaller, but a large increase in the rate was observed from 550° to 600°C. From 600° to 1,000°C. there was practically no increase in dimensions. The cooling curve nearly coincided with the heating curve so that the abrupt changes in length at 150° to 250°C. and 550° to 600°C. were reversible and were evidently due to the inversion of α-to β-cristobalite and of α-to β-quartz respectively. The actual expansion to 1,000°C. was the same as for the test piece fired to cone 06. The behaviour of the quartzite was thus different from that of the ganister in that once burning to cone 9 had converted some of the quartz into cristobalite, and had not appreciably decreased the expansion between 15° and 1,000°C. The specific gravity of the quartzite had decreased to 2·58, a result which was in agreement with the changed character of the expansion curve. The index of refraction of all the material was greater than 1·481 and of nearly all greater than 1·503, indicating quartz mixed with a small amount of cristobalite.

Cone 14. (Fig. 10, curve D.). The specimen was next fired in the laboratory for two hours at cone 14, which produced a permanent expansion of 2·6 per cent. It was again examined in the expansion apparatus. The length increased regularly up to 200°C.,

but from 200° to 250°C. an extremely rapid expansion occurred amounting to 0·75 per cent. of the original length of the test piece. From 250° to 550°C. the sample expanded regularly, but from 550° to 600°C. there was the usual rapid rate of expansion always observed with quartz. The quartz expansion was, however, only about one-third of that noted after burning at cone 9. A slight expansion took place from 600° to 800°C., after which the test piece contracted slightly to 1,000°C. The cooling curve was almost identical with the heating curve so that the rapid expansions noted between 550° and 600°C. and 200° and 250°C. were reversible and must be associated with the inversion of α to β quartz and α to β cristobalite respectively. This result was supported by a determination of the specific gravity which was 2·35, a value which would agree with a large amount of cristobalite (specific gravity 2·33) associated with some quartz (specific gravity 2·65). A microscopic examination of the powdered specimen showed it to consist of a mixture of quartz and cristobalite. No tridymite could be detected, all the material having an index of refraction greater than 1·481.

Cone 20, (1,510° to 1,520°C.) (see Fig. 10, curve E.). The test piece was next fired for two hours in a laboratory furnace at 1,510° to 1,520°C. and its expansion again determined. The expansion-temperature curve was practically along the one obtained for the cone 14 test piece up to 200°C., but from this point to 250°C. there was a somewhat greater expansion. From 250° to 550°C. the expansion was small but regular, while from 550° to 750°C. the rate of expansion was smaller. No rapid expansion between 550° and 600°C. could be detected, thus indicating the absence of quartz from the specimen. From 750° to 1,000°C. a slight contraction was noted. The rapid expansion between 200° and 250°C. was again reversible and was due to the α- to β-cristobalite inversion. It would seem that the whole of the quartz had been converted into cristobalite, a result which was confirmed by the specific gravity which had become 2·33. The refractive index of all save one or two grains was between 1·481 and 1·503 so that this microscopic examination also showed that the quartzite had been converted completely into cristobalite, the few grains with index of refraction greater than 1·503 probably being silicates.

Summarising, the quartzite on burning to cone 06 showed only a small permanent expansion and was still unconverted quartz. Firing to cone 9 converted part of the quartz into cristobalite, the conversion being considerably increased on burning for two hours at cone 14, and completed after a further heating at cone 20 for two hours. No evidence of the conversion of the quartzite into tridymite was observed. The conversion of the quartz into cristobalite brought about a larger expansion from 15° to 1,000°C. after burning at cone 14 or cone 20 than after firing to cone 06 or cone 9. By far the greater part of the expansion, however,

had been brought into the range 15° to 300°C., the increase in length being small between 300° and 1,000°C. This result bears distinctly on furnace practice. With bricks in which the quartz had been converted into cristobalite by hard-firing, no strain and danger of fracture would result from fluctuations of temperature between 1,000° and 300°C., after the temperature of 300°C. had been once attained, whereas with lighter burned bricks containing quartz strain would result whenever the temperature fell below 600°C. The large and rapid expansion up to 300°C. for the material fired to cone 14 and upwards emphasised, however, the necessity for slow and careful heating in the initial period of heating if expansion strains were to be avoided. It may be mentioned that the contraction from 600° to 500°C. for the quartzite before its appreciable conversion into cristobalite was not very different from the expansion observed in this range—a result very different from that obtained for the Meanwood ganister, plaster being used in each case as a binder.

Flint. The differences noted between the expansions of specimens prepared in the same manner from Meanwood ganister and from the Welsh quartzite suggested the necessity of studying the changes produced by heating some other form of quartz in the presence of a lime bond. Flint was selected and a similar series of tests carried out. In the first experiment the raw flint was ground to pass a 20-mesh standard I.M.M. sieve as in the preceeding experiments, but in the other tests in this series flint ground to flour as used in the pottery industry was taken, the flints having been calcined to 1,000°C. before grinding. In each case 3 per cent. of plaster was used to bind the specimens.

Uncalcined Flint. (Fig. 13, curves C, D, and E.). The uncalcined flint gave a rather different expansion-temperature graph from those for Meanwood ganister and quartzite. It showed the increased rate of expansion between 500° and 600°C. indicative of the α—β-quartz inversion, but this rapid rate of expansion extended to 700°C. The specimen expanded at a much smaller rate from 700°C. to 850°C. after which a slight contraction was noted. On cooling the specimen showed little change of length from 1,000 to 650°C. but a rapid contraction took place from this point to 450°C. A smaller rate of contraction was noted from this temperature to 15°C. and the specimen showed a permanent expansion of 0·36 per cent. The second heating curve was very similar to the one obtained for calcined flint next described.

Flint calcined at about 1,000°*C. previously to grinding.* (Fig. 11, curve B.). The expansion-temperature graph was almost identical with those obtained for unfired ganister and quartzite. After heating overnight at 1,000°C. a permanent contraction of 0·33% was noted.

Flint burned at cone 06. (Fig. 11, curve C.). The heating and cooling curves of the flint dust after firing in a works kiln to

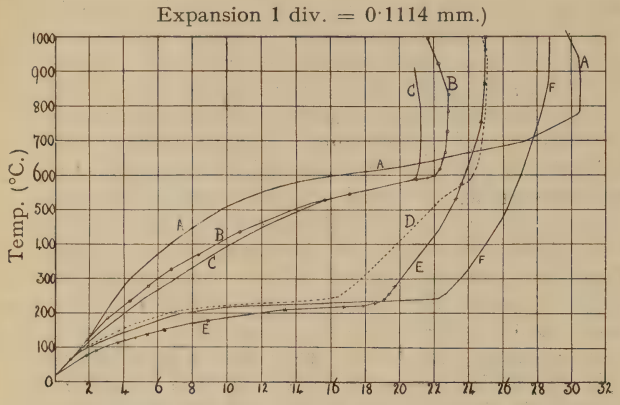


Fig. 11.

FLINT WITH LIME BOND.

A. Unfired.
B. Calcined.
C. Burned at Cone 06.
D. ,, ,, 9.
E. Heated for 2 hrs. at Cone 13—14.
F. Heated for 2 hrs. at 1510—1550°C.

cone 06 were similar to those given by the material after heating in the expansion apparatus to 1,000°C. Its density was 2·56 which agreed with that for the calcined flint before firing at cone 06. The whole of the material had a refractive index greater than 1·503 and was therefore unaltered quartz.

Flint burned at cone 9. (Fig. 11, curve D.). A change in the character of the expansion temperature graph was observed after the flint had been burned in a works kiln to cone 9. A large expansion from 15° to 200°C. was succeeded by an extremely large increase in length of the specimen between 200° and 230°C. From 230° to 550°C. the rate of expansion was less than from 15° to 200°C. but this was again increased from 550° to 600°C. The increase in length from 600° to 900°C. was small, and from 900° to 1,000°C. a slight contraction took place. The cooling curve was similar to the heating curve so that the increased rate of change in dimensions at 550° to 600°C. and at 200° to 230°C. were reversible and were to be attributed to the α- to β-quartz and the α- to β-cristobalite inversions respectively. The expansion curve suggested that the flint now consisted of quartz and cristobalite, the latter being in excess, and the density (2·39) agreed with this deduction. None of the specimen had a refractive index less than 1·481 so that tridymite was absent, while some of the powder had a refractive index greater than and some less than 1·503, suggesting again quartz and cristobalite.

Flint burned at cones 13–14. (Fig. 11, curve E.). A test piece which had been burned to cone 9 was fired for two hours to cone 13—14 in the laboratory before examination in the apparatus. A large reversible expansion was again noted from 100° to 230°C., but no increase in the rate of expansion was detected between 550° and 600°C. which suggested that the quartz had been completely transformed. The cooling curve differed very little from the heating curve, although a slight permanent expansion (0·06

per cent.) was observed, and the expansion on the second heating was less than that on the first heating by approximately this amount. The specific gravity of the substance was 2·33, a value identical with that of cristobalite. The bulk of the powdered material had an index of refraction between 1·503 and 1·481 and was, therefore, cristobalite. A little had a refractive index greater than 1·503 and a little had an index less than 1·481 so that a trace of tridymite and a trace of quartz (or silicates) were associated with the cristobalite.

Flint burned at 1,510° *to* 1,550°*C.* (*about cone* 20). (Fig. 11, curve F.). It was found that the previous test piece after a further heating for two hours in a laboratory furnace at 1510° to 1,550°C. behaved very much as before but had a greater expansion between 100° and 230°C. Again, no evidence of quartz could be detected and the expansion temperature graph suggested that the whole of the test piece was cristobalite. Microscopic examination failed to detect any quartz, the material being entirely cristobalite (refractive index between 1·503 and 1·481), apart from isolated grains. The specific gravity was 2·34.

Summarising, it appeared that the flint with a lime bond was converted with greater ease on heating into cristobalite than either the Welsh quartzite or the Meanwood ganister, the change being almost complete at cone 9 and complete at cone 14. The Welsh quartzite also transformed readily into cristobalite but not with the same facility as flint. In this case the change started at cone 9, but was not completed until cone 20. Meanwood ganister with a lime bond showed practically no trace of inversion at cone 9, but the change started at cone 14.

Probably the more rapid conversion of the flint into cristobalite was due to its physical state—very small crystals embedded in colloidal silica—but other possible causes were considered, viz. :—

1. The fineness of grinding of the flint.
2. The presence of a greater amount of lime (the flint without the addition of plaster contained over 1 per cent. of lime). or
3. The possible presence of small traces of phosphates. Rebuffat* has recently stated that small quantities of phosphates assist the transformation of quartz into tridymite.

In order to test the first possibility some of the Welsh quartzite was ground to fine flour like the flint, and test pieces were prepared in the usual way. After burning to cone 9 the test piece of quartzite flour showed nearly double the expansion from 200° to 250°C. of that obtained for the same quartzite ground to pass a 20-mesh sieve, while the expansion from 500° to 600°C. had been reduced (see Fig. 10, curves C. and F.). Fine grinding had evidently facilitated the transformation of the quartz into cristobalite,

* *Giorn. Chim. Ind. Appl.*, **2**, 437, 1920 (*cf.* p. 66).

although the difference in the rates of transformation of quartzite and ganister into the lower density forms of crystalline silica cannot be attributed to size of grain since in both sets of experiments these materials were ground to pass the same 20-mesh sieve.

The second possibility has not yet been tested, but will be examined later in a more general investigation of the effect of fluxes in bringing about the transformations of silica.

Tests were made for the presence of phosphates in the ganister and flint, but gave negative results.

There is reason for thinking, therefore, that the fineness of division of flint may be ranked as a factor operative in determining its comparative ease of conversion into cristobalite. Mellor and Campbell* had previously observed that flint passed more readily than quartzite into a form of silica of lower density.

The whole of the experiments so far discussed showed that cristobalite is produced from quartz much more readily than is tridymite and in much greater quantity. In fact tridymite had only been produced in excess and in precipitated silica (containing soda) heated to 1,170° C. or to cone 14 and in vitreosil heated to 1,550°C. Long exposures at high temperatures to which silica bricks are subjected in industrial furnaces had not, however, been tried and that was the next step.

Commercial Silica Bricks. So far only specially prepared test pieces had been used. Experiments were now conducted on commercial silica bricks, two of them being made from the Welsh quartzite we had studied by kilning at about cone 16. Silica bricks of the same manufacture were also examined after use in coke ovens and steel furnaces.

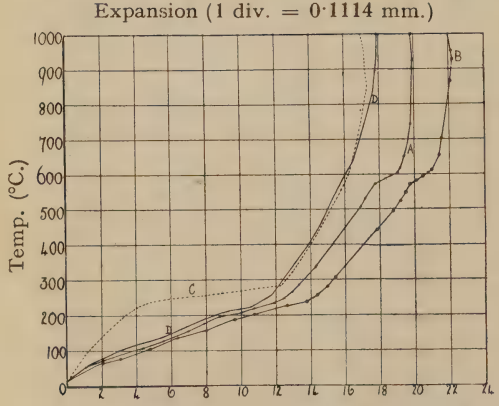


Fig. 12.

A. Commercial Silica Brick made from Welsh Quartzite.

B. Ditto but containing 25% Silica Flour.

C. Brick A after 12 weeks' use in gas-port of Steel Furnace.

D. Commercial Silica Brick from Quartzitic Pebbles (S. Yorkshire).

Sample A. (see Fig. 12, curve A.). The first brick examined was one made from Welsh quartzite (Bwlchgwyn). A test piece was cut from the actual brick and examined. A very large co-

* J. W. Mellor & A. J. Campbell, TRANS., **15**, p. 80, 1915.

efficient of expansion was observed from 15° to 250°C. followed by a considerably smaller, but regular, expansion to 550°C. From 550° to 600°C. the rate of expansion was considerably increased. A small coefficient of expansion was found between 600° and 750°C., and from this temperature to 1,000°C. there was a slight contraction. The large expansion up to 250°C. could be associated with the transformations of much cristobalite, whilst the increased rate of expansion from 550° to 600°C. would correspond with the inversion of α–quartz into β–quartz. Owing to the large expansion accompanying inversion of the cristobalite the expansion of the brick from 15° to 1,000°C. was more than double that of a fireclay brick. It would demand slow and careful heating with no rigid ties when the structure was first heated, and would be a source of danger from cracking and opening-out of the brickwork if the furnace, etc., had to be let down below 300°C. The specific gravity of the brick was 2·40. Microscopic examination of the powdered brick showed it to be a mixture of quartz and cristobalite with no tridymite.

Sample B. (Fig. 12, curve B.). This was cut from a commercial brick prepared from the same quartzite as sample A, but containing 25 per cent. of quartzite flour (98 per cent. passing through a 200-mesh sieve). Its expansion temperature curve was of the same form as that for sample A, but its expansion from 15°C. to 250°C. was greater than, and that from 550°C to 600°C. less than, was observed for the brick made without the addition of quartzite flour. This result agreed with that obtained for quartzite flour burned at cone 9 and already described.

Sample C. (Fig. 12, curve D.). This brick was made from quartzitic pebbles occurring near Bawtry (Yorkshire). We have made no expansion tests on the raw material from which it was manufactured. The expansion of a test piece cut from this brick was very similar to those of the previous specimens up to 550°C., *i.e.*, it showed a large expansion to 250°C. such as might be explained by the tridymite or cristobalite inversions and a regular but smaller rate of expansion from 250° to 550°C. At this stage a difference was observed, for no discontinuity between 550° and 600°C. arising from free quartz was detected. Instead, the brick expanded fairly regularly to 900°C. after which there was no further expansion to 1,000°C. Apparently all the quartz had been converted into other forms of silica. The large expansion from 15° to 200°C. would be explained by the presence of tridymite and cristobalite. The specific gravity of the brick was 2·35. Determinations of the refractive indices of the particles of the powdered brick showed it to consist chiefly of cristobalite mixed with a very small amount of tridymite and some material of refractive index greater than 1·503, probably silicates. No quartz could be detected in a microsection cut from this brick.

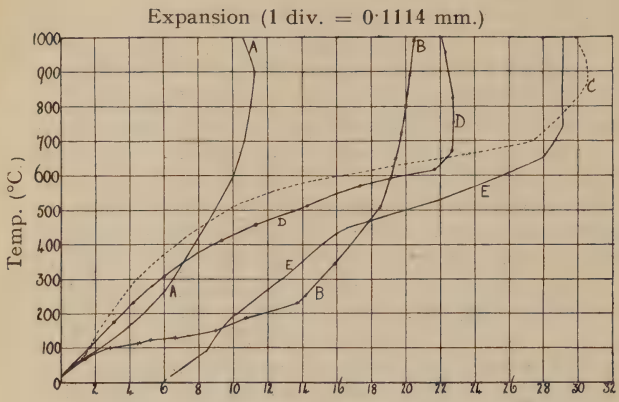


Fig. 13.

SILICA BRICK A AFTER USE IN COKE OVEN.

A. Innermost layer near exposed surface

B. Other layers.

C. 1st heating of uncalcined flint

D. 2nd Ditto.

E. 1st cooling of uncalcined flint.

Silica brick after use in a coke oven (*see Fig.* 13, *curves A and B.*). A silica brick of the same manufacture as sample A was examined after fourteen months service, at a probable maximum temperature of 1,450°C., in a coke oven. On dividing the brick, four fairly distinct layers were noted. The innermost layer next the exposed face was greyish-black with large white grains clearly distinguishable, and a brownish-black outer crust. This layer was about six-tenths of an inch thick, and was followed by a one-inch layer of light brown material. The next layer was dark brown, one-and-a-half inches thick, and was succeeded by a light brown layer about one-inch thick. This last part looked very much like unaltered brick. Owing to the cracks which had developed during use it was not possible to cut test pieces from the brick. It was separated into the four layers and separate test pieces were prepared from them. They were ground until they passed a 20-mesh standard (I.M.M.) sieve, 3 per cent. plaster added, the mixture wetted, moulded, dried and fired in a laboratory furnace until cone 01 was just bending. It was necessary to see whether this treatment altered the expansion of the material in any way. Accordingly the expansion of a specimen cut from an unused silica brick was compared with that of one prepared from the same brick powdered with the addition of plaster as described above and fired in the laboratory until cone 01 was just bending. (Specimens made from the powdered used brick without this preliminary heating were liable to break under examination). The expansions of the two specimens were practically identical as will be seen by reference to the coefficients of expansion given in Table 4. It was, therefore, assumed that no appreciable error was introduced by preparing specimens from the ground material in the manner described. The innermost black contaminated layer gave the curve shown in Fig. 13, curve A. The expansion curve obtained for the material from this layer showed none of the breaks which we were accustomed to get from material containing quartz, cristobalite, or tridymite. The co-

efficient of expansion diminished slowly and continuously as the temperature rose. It was such as might be expected from a contaminated quartz glass and the total expansion was only half that of the layers behind it. The results of microscopic examination by refractive index taken alone would suggest that about half of the material was cristobalite and half quartz and silicates of higher refractive index, but if that were so the cristobalite and quartz had not exerted their characteristic effects in the expansion test. The composition of the material in the layer can be expressed empirically by the formula RO ; 0·4 Al_2O_3 ; 14·3 SiO_2. The outer crust which was obviously partially fused was, no doubt, richer in basic material including ferric oxide. The expansion temperature curves obtained for the other three portions of the brick were practically identical, and the actual expansion from 15° to 1,000°C. was in each case almost the same as that obtained for the unused silica brick. The character of the curves, however, was somewhat different from that given by the unused brick. There was a rather more rapid expansion from 15° to 150°C. and practically no sudden expansion at 550° to 600°C. Above 600°C. also the specimens continued to expand, whereas the unused silica brick contracted slightly above 700°C. It would seem that the long heating to which the brick had been subjected had completely transformed the original quartz of the brick. The refractive index of the material of these layers was almost throughout less than 1·503 and greater than 1·481 so that the microscopic examination declared them to be cristobalite associated with a little tridymite and quartz or silicates of higher refractive index. The difference in the expansion between the outer darker layer and the remainder of the brick demonstrated one cause of wearing of the brick in use. The expansion from 15° to 1,000°C. of this darker layer was only about one-half that of the rest of the brick, so that fluctuations of temperature would cause great strain to be set up between these two parts of the brick, with the consequent cracking off of the inner darker layer.

Silica brick after use in the roof of a Steel Furnace. Commercial silica bricks made from the same Welsh quartzite were examned "after twelve weeks use at a probable maximum temperature of 1,600° to 1,650°C. in the roof of an open hearth steel furnace." On splitting, each brick showed four fairly distinct layers (see Fig. 14).

(*a*) *Innermost layer next the face exposed in the furnace and highest in temperature.* (Fig. 15, curve A). A test piece was cut from this layer of the brick and examined in the apparatus. It expanded steadily from 15° to 240°C., but from this point to 280°C. a large and rapid expansion took place so that the temperature expansion graph was almost parallel to the expansion axis. From 280° to 630°C. the rate of expansion was less than from 15° to 240°C. No discontinuity in the expansion was detected at 550° to 600°C. such as would be expected if free quartz was present. The co-

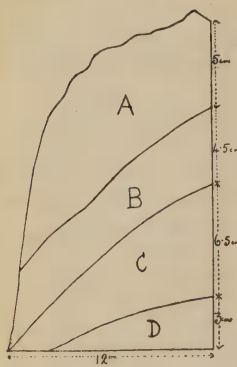


Fig. 14.

Section of Brick from Roof of Steel Furnace.

A. Innermost layer next the exposed face; grey to slaty-black; honeycombed; vitrified; white grains not seen.

B. 2nd layer; black to dark grey, with few large white grains; semi-vitrified and honey-combed

C. 3rd layer; light grey colour with large white grains and specks of yellow.

D. 4th layer; reddish in colour.

efficient of expansion above 630°C. continually decreased until no further expansion occurred between 900° and 1,000°C. The large expansion from 240° to 280°C. was reversible on cooling but occurred at a lower temperature (220° to 200°C.). It was presumably due to the α to β cristobalite inversion. Apparently neither quartz nor tridymite was present in quantity. Microscopic examination showed that the bulk of the material was cristobalite having a refractive index between 1·503 and 1·481. About one-eighth of the powder had an index of refraction greater than 1·503 and probably consisted of silicates. A small quantity had a refractive index less than 1·481 and was probably tridymite.

The expansion of a test piece cut from a silica brick had already been compared with that of a sample prepared from the powdered brick and no appreciable difference had been found. It was considered wise, however, to again test this point by comparing the expansion of the test piece cut from the hot layer of the brick from the roof of a steel furnace with that of one prepared from the powdered material. The substance was passed through a 20-mesh standard (I.M.M.) sieve, mixed with 3 per cent. plaster added as slip, moulded and dried. It was than heated in the apparatus to 1,000°C. and the expansion curve for the second heating taken. It was almost identical with that obtained with the test piece cut from the brick, again justifying the use of the powdered material. Owing to the difficulty and almost impossibility of getting test pieces free from cracks from the brick, the experiments with the other layers were performed with test pieces prepared from the powdered brick.

Second layer of brick used in roof of Steel Furnace. (Fig. 15, curve B.). This part of the brick expanded quite differently from the hottest portion. Its length increased steadily and at a fairly rapid rate to 300°C., after which the rate of expansion decreased gradually with increasing temperature until there was a slight contraction between 900° and 1,000°C. The cooling curve was similar to the heating curve. No marked discontinuity occurred.

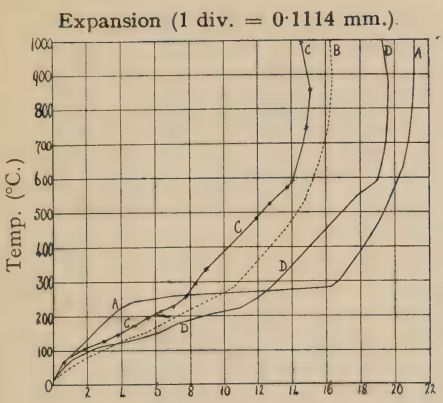


Fig. 15.

Silica Brick after 12 weeks in Roof of Steel Furnace.

A. 1st (hottest) zone.
B. 2nd zone.
C. 3rd zone.
D. 4th (coldest) zone.

The total expansion to 1,000·C. was about four-fifths, and that from 15° to 300°C. about three-fifths, of that of the hottest layer, again showing the possibility of strains and cracks developing owing to the different rates of expansion of the two layers. Examination of the powdered sample showed about half the material had a refractive index greater than 1·503, that of the other half being between 1·503 and 1·481. A very few particles had a refractive index less than 1·481 and were probably tridymite. Thus microscopic examination indicated that almost half the material in this layer was cristobalite while the other half had a refractive index greater than 1·503. As no quartz was detected in the expansion test the latter portion was probably chiefly silicates. A very small amount of tridymite was also present.

Third layer of the brick used in roof of Steel Furnace. (Fig. 15, curve C.). The total expansion from 15° to 1,000°C. of the third layer was not very different from that of the second layer but the form of the curve was somewhat different and there was evidence of the α–toβ–quartz inversion. The microscopic examination of the powdered material gave similar results to those obtained for the second layer, but taking these in conjunction with the expansion of the test piece it seemed probable that some quartz and less silicates were present along with cristobalite in quantity.

Fourth layer of brick used in roof of Steel Furnace. (Fig. 15, curve D.). The expansion of this test piece did not differ appreciably from that of the unused brick, and microscopic examination of the powdered material immersed in oils of known refractive indices also gave similar results to those obtained for the unused bricks, *i.e.*, this layer consisted of a mixture of quartz and cristobalite with a very small amount of tridymite.

The examination of a similar brick after use in the roof of a steel furnace has been described by C. S. Graham.* He found

* Trans., **18**, pp. 399—406, 1919.

from the microscopic examination of thin sections that the hottest layer consisted of crystals of cristobalite surrounded by a ferruginous glass. In the second layer the quartz was completely inverted and consisted of tridymite and cristobalite embedded in a ferruginous matrix. In the third layer he observed that some of the quartz rock fragments had undergone a change, although unconverted quartzite was still present, while in the part corresponding to the fourth layer in our experiments he found the fragments of quartz rock had undergone little change, but that in the ground mass some of the irregular quartz grains had disappeared and had been replaced by very small crystals. These conclusions are very similar to those we have reached by our experiments.

Brick from gas-port of Steel Furnace. (Fig. 12, curve C.). A silica brick of the same manufacture was tested after use in the gas-port of a steel furnace for twelve weeks. The lines of demarcation between the different zones were much less marked than was observed in the brick from the roof of the furnace as would be expected from the conditions of heating. The brick was divided into three layers. The expansion temperature graphs of the hottest and middle zones were identical. They expanded steadily and fairly rapidly to about 220°C. when a large and rapid expansion occurred to 280°C. After this temperature, the rate of expansion was smaller, and above 600°C. the coefficient of expansion decreased with increasing temperature until from 900° to 1,000°C. the specimen contracted slightly. No evidence of the α to β quartz inversion could be detected. The third layer expanded similarly, but the actual expansion was slightly greater. In each case the large and rapid expansion between 220° and 280°C. was reversible on cooling, but occurred 20° to 30°C. lower than on heating. In each case examination of the powdered material showed that about two-thirds of it had an index of refraction between 1·481 and 1·503 and was cristobalite, the remaining one-third having an index of refraction greater than 1·503. In view of the data from the expansion curves the bulk of this probably consisted of silicates.

SUMMARY.

The reversible linear expansions of various forms of silica, raw and manufactured, were determined, and along with them permanent changes in specific gravity and refractive index. Transformations were often found to occur and are indicated in accepted terms of mineralogical composition. *Pure amorphous precipitated silica* was studied as offering probably the most favourable conditions for transformation. It underwent no change at 700°C. even on prolonged heating, but after heating at 1,170°C. or cone 14 showed the great expansion between 200° and 300°C. characteristic of cristobalite (with a little tridymite). *Precipitated silica containing 5 per cent. soda* showed the cristobalite expansion between 200° and 300°C. after heating at 700°C., but heating at 1,170°C. or at

cone 14 gave the smaller (tridymite) expansion between 100° and 170°C. and some cristobalite. The presence of the soda was apparently responsible for the formation of cristobalite at a lower temperature, and for the formation of tridymite.

Silica glass (*vitreosil*) gave very little thermal expansion but the refractive index corresponded with the formation of tridymite, to a small extent at cone 14 and to a considerable extent at cone 20.

Although almost all naturally occurring silica deposits are quartzitic, quartz was not formed from amorphous silica in any of the experiments above described. Probably the natural deposits, or their nuclei upon which more quartz crystals could grow, were formed under great pressure, which was absent in our experiments.

Raw materials for silica refractories.

(*a*) *Meanwood ganister* with lime bond showed the large quartz expansion between 500° and 600°C. and no cristobalite after a works burn to cone 9 (with an actual maximum temperature of 1,170°C.), but a little cristobalite along with quartz after a laboratory burn to cone 14, and more cristobalite at cone 19, *i.e.*, a large expansion between 100° and 250°C. and only a small reversible expansion between 550° and 600°C. Repeated works firing at cone 9, however, gave a little cristobalite even without bond.

(*b*) *Welsh Quartzite* with lime bond transformed more easily. It gave a little cristobalite in the quartz at cone 9 (works burn), more at cone 14, and all cristobalite at cone 20.

(*c*) *Flint* with lime bond transformed more easily still. It gave some cristobalite at cone 9, nearly all at cone 14, and all at cone 20.

None of these three raw materials gave tridymite in any quantity. All of them underwent a considerable permanent linear expansion in the lower temperature ranges before any conversion of quartz occurred. The true specific gravity and refractive index were not altered thereby but the porosity increased. The amount of the change differed in the three materials, and it is probably important as determining largely the toughness of the fired quartz particles and their liability to crumble or break after firing.

Silica Bricks as Manufactured.

(*a*) *From Welsh quartzite, fired at cone* 16. This brick showed the large cristobalite expansion between 200° and 300°C. and also some quartz expansion between 500° and 600°C.

(*b*) *From Yorkshire quartzitic pebbles.* This brick showed the α to β cristobalite expansion, but no α to β quartz expansion between 500 and 600°C. A little tridymite may have been present.

Silica Bricks (*from Welsh Quartzite*) *after long use.*

(*a*) *In coke oven* (maximum temperature 1,450°C.). The innermost exposed layer was an impure glass with a steady expansion but only half as large between 15° and 1,000°C. as that of the layers behind, which will make for shelling away. The rest of the brick was all cristobalite with very little quartz or tridymite.

(*b*) *From steel furnace roof* (maximum temperature 1,600° to 1,650°C.). The layer exposed to the furnace heat was practically all cristobalite and silicates, the next layer the same, the third layer showed some α – to β – quartz expansion at 550° to 600° as well as the α – to β – cristobalite expansion, while the fourth outermost layer exposed to air was similar to the brick before use.

In these bricks the exposure to high temperature had evidently completed the change from quartz to cristobalite which had been largely effected in the kiln during manufacture. Little or no tridymite had formed.

The volume changes in manufacture and use of a silica brick may therefore be traced thus:

First, on burning, the quartz undergoes a permanent linear expansion, with little or no decrease in specific gravity, but an increase in porosity. This permanent expansion may be about half per cent. even below 1,000°C. and considerably more at cone 9. The toughness may appreciably alter in consequence. The further burning to cone 14—16 alters the expansion curve, changing the quartz completely or partially, according to the nature of the raw material and the time and temperature of burning, into cristobalite. This means that the sudden α – to β – quartz expansion between 500° and 600°C. is replaced by the α – to β – cristobalite expansion between 200° and 300°C. The total reversible expansion is not lessened. The furnace of "cristobalite" bricks is therefore much less subject to expansion strain at dull redness than one of "quartz" bricks, although more so below 300°C. Neither is at all sensitive above 600°C. Long exposure in use at high temperatures completes the conversion of quartz to cristobalite. Apart from actual test in the expansion apparatus, we have found that a determination of the true specific gravity of the powdered brick is the best guide to its behaviour as regards expansion and contraction.

(Specific gravity of quartz=2·65).
(Specific gravity of cristobalite=2·33).

The reversible thermal linear expansions from 15—1000°C of the materials examined were approximately as follows:—

	Meanwood Ganister	Welsh Quartzite	Flint
Before firing	0·8%	1·3%	1·4%
Fired to Cone 9 with changes in structure of quartz, but without much transformation into cristobalite ..	0·7%	1 3%	1·5%
Fired to cone 14 with some transformation into cristobalite	0·5%	1·5%	1·5%
Fired to Cone 20 with fairly complete transformation into cristobalite	0·6%	1·5%	1·7%

The reversible thermal expansion from 15—1000°C of the commercial silica bricks examined was 1·1 to 1·3%.

In conclusion our thanks are due to Mr. G. R. Thompson and Messrs. The Farnley Iron Co. for the kiln firing of test pieces, and to Mr. T. A. Acton, Messrs. The Bwlchgwyn Roadstone Co. Ltd., Messrs. Yorkshire Refractories Ltd., and Messrs. Lysaght Ltd., (Scunthorpe) for the provision of specimens.

TABLE II.

CHEMICAL ANALYSES OF THE MATERIALS EXAMINED.

	Meanwood ganister without bond	Meanwood ganister with lime bond	Welsh quartzite without bond	Flint (calcined) without bond	Precipitated silica after heating to 700° C.	Silica Brick A.	Silica Brick C.	Silica Brick A after use in coke oven 1st innermost layer
Loss on ignition (L.I.)	—	—	0·26	1·47	1·66	—	—	0·11
Silica (SiO_2) ..	97·3	96·04	98·78	93·83	91·06	93·79	94·24	87·21
Alumina (Al_2O_3)	1·15	1·42	0·12	1·67	—	1·56	1·32	4·16
Titania (TiO_2) ..	0·26	0·05	0·12	0·04	—	0·12	0·25	0·27
Ferric Oxide (Fe_2O_3)	0·94	0·27	0·91	0·88	0·79	1 30	1·69	3·0
Lime (CaO) ..	0·31	2·0	0·08	1·14	0·34	3·07	1·79	3·36
Magnesia (MgO)	Tr.	Tr.	Tr.	0·09	—	Tr.	0·04	0·01
Potash (K_2O) ..	—	0·22	0·27	0·63	0·52	0·15	0·63	1·09
Soda (Na_2O) ..	—			0·13	5·12			1·35

TABLE III.

POROSITY AND BULK AND TRUE SPECIFIC GRAVITIES OF THE MATERIALS TESTED.

$$\left(\text{POROSITY} = \frac{\text{Weight of paraffin absorbed by specimen}}{\text{Loss in weight of saturated specimen on weighing in paraffin.}}\right) \quad \left(\text{BULK SPECIFIC GRAVITY} = \frac{\text{Weight of specimen}}{\text{Total volume of specimen}}\right)$$

	Temperature of previous burning	Porosity	Bulk specific gravity	True specific gravity
Precipitated silica	700°C.	67·4	0·75	2·30*
	cone 9	63·3	0·83	2·28*
	cone 14			
Meanwood ganister without bond	Unfired			2·65
	cone 9 (6 burns)	21·9	2·02	2·59
	cone 14	21·9	2·01	2·59
	cone 20	29·5	1·64	2·32
Meanwood ganister with bond	Unfired	35·6	1·68	—
	cone 06	40·2	1·60	2·67
	cone 9	39·9	1·57	2·61
	cone 14	32·3	1·69	2·49
	cone 20			
Welsh quartzite with bond	Unfired			2·64
	cone 06	34·4	1·68	2·63
	cone 9	36·6	1·62	2·58
	cone 14	39·7	1·43	2·35
	cone 20	44 7	1·28	2·33

[*Contd.*

* From porosity determination.

TABLE III.—*Contd.*

	Temperature of previous burning	Porosity	Bulk Specific gravity	True specific gravity
	Unfired			
	Calcined	43·4	1·43	2·56
	cone 06	47·5	1·36	2·56
Flint with bond	cone 9	43·8	1·35	2·40*
	cone 14	43·4	1·32	2·33
	cone 20	27·7	1·70	2·34
Silica Brick A		26·0	1·78	2·40*
Silica Brick B		26·8	1·76	2·40*
Silica Brick C		27·9	1·68	2·35
Silica Brick A after use in coke oven—				
1st (next the exposed face) layer		20·6	1·89	2·37*
2nd layer		29·0	1·67	2·33*
3rd layer		29·6	1·62	2·30*
4th layer		30·1	1·59	2·28*
Silica Brick A after use in roof of steel furnace—				
1st (hottest) layer		8·6	2·24	2·45*
2nd layer		7·3	2·27	2·45*
3rd layer		5·3	2·19	2·32*
4th layer		28·1	1·72	2·39*
Silica Brick A after use in gas port of steel furnace—				
1st (next exposed face) layer		7·3	2·20	2·37*
2nd layer		11·2	2·26	2·50*
3rd layer		8·0	2·29	2·49*

* From porosity determination.

TABLE IV.

COEFFICIENTS OF EXPANSION $\times 10^{-7}$

Substance	Temp. range (°C.)	Temperature of prior firing				
		Unfired	Cone 06	Cone 9	Cone 14	Cone 20
Meanwood ganister without bond.	15–1000	180	—	107	104	107
	15– 500	204	—	148	154	200
	200– 250	—	—	240	284	975
	500– 600	696	—	362	295	30
	600–1000	23	—	–4	–·2	16
Meanwood ganister with lime bond.	15–1000	136	75	68	55	62
	15– 500	145	87	89	74	93
	100– 250	—	—	—	99	158
	250–500	—	—	—	62	47
	500– 600	573	323	250	116	58
	600–1000	12	5	11	106	26
Welsh quartzite lime bond.	15–1000	136	122	128	155	153
	15– 500	163	172	192	279	298
	200– 250	—	—	396	1454	1721[a]
	500– 600	579	417	289	139	44
	600–1000	–4	–4	14	11	7
Flint with lime bond	15–1000	174 (calcined) 128	136[b]	146	146	168
	15– 500	116 (calcined) 164	170	255	270	306
	20– 250	—	—	1031	1073[c]	1615
	500– 600	384 (calcined) 467	378	150	55	55
	600–1000	331 (calcined) 3	6[b]	15	25	32

		Temperature of prior firing		
		700°C.	1170°C.	Cone 14
Pure amorphous silica.	15–1000	—	166	224
	160– 200	—	1900	—
	200– 250	—	—	1744
Precipitated silica containing soda.	15–700	132	—	—
	15–1000	—	92(Cone 9)	—
	100– 170	101	467	—
	170– 225	948	259	—
	225– 500	97	127	—

[*Contd.*

TABLE IV.—*Contd.*

Substance	Temp. Range (°C.)		
			(From powdered brick)
Silica Brick A.	15–1000	118	112
	15– 250	304	303
	250– 500	101	161
	500– 600	127	105
	600–1000	17	16
Silica Brick B.	15–1000	131	
	15– 250	344	
	250– 500	108	
	500– 600	111	
	600–1000	23	
Silica Brick C.	15–1000	107	
	15– 250	280	
	250– 500	84	
	500– 600	61	
	600–1000	31	
Silica Brick A after use in coke oven.			
(*a*) Innermost layer	15–1000	65	
(*b*) Other layers ..	15–1000	121	
	15– 250	340	
Silica Brick A after use in roof of steel furnace.			
(*a*) Innermost (hottest) layer	15–1000	125	
	200– 300	746	
(*b*) Second layer ..	15–1000	98	
	15– 250	231	
(*c*) Third layer ..	15–1000	88	
	100– 250	232	
	250– 500	106	
	500– 600	117	
	600–1000	13	
(*d*) Fourth (coldest) layer ..	15–1000	115	
	100– 250	369	
	250– 550	117	
	550– 600	139	
	600–1000	12	
Silica Brick A after use in gas port of steel furnace.	15–1000	102	
	220– 280	787	

a. 220°—270°C.
b. 15°—900°C.
c. 160°—220C.

DISCUSSION.

Mr. ARTHUR ACTON:—I am sure all who are interested in silica, and especially those of you who are concerned with the manufacture of silica brick, will feel how much we are indebted to Mr. Houldsworth and Prof. Cobb for the very lucid explanations which they have given us of a difficult subject. In our deliberations in the Ceramic Society, I think some of us began to flatter ourselves that we were beginning to learn something about silica. Unfortunately, however, as our Society gets older, we find that the mass of literature and facts that are gradually accumulating, look as though they are likely to bury us before we are through. It would be pure presumption on my part to attempt to offer any criticism upon this valuable paper, upon a first glance. It will provide us with a good deal of matter for careful thought during the coming winter. I trust that Mr. Houldsworth and Prof. Cobb will continue these interesting investigations. Having supplied some of the raw material upon which the authors have been working, I am specially interested in these results.

It is particularly interesting to find that the investigations as to the conversion of quartz into cristobalite seemed to agree with, and to corroborate the researches of Dr. H. H. Thomas, which were published in the *Memoirs of the Geological Survey, Vol.* 16, 1920. In connection with that work there appeared an interesting set of petrological micro-sections. The main point is, however, that the conclusions arrived at were very much those which have been reached by the authors of the present papers. Perhaps you will remember that when we first discussed this question, the dream of all of us who are interested in the manufacture of silica bricks was to produce a tridymite brick. I myself was always somewhat sceptical as to the commercial possibility of this. I agree with Mr. Houldsworth that the most ready method of investigating the proportion of unconverted and converted quartz is that of powdering, and using various chemicals which show the refractive index of the various forms of silica. Personally, I used to fancy that I saw a great deal more tridymite than I ever did. Sometimes one would see a fused crystal of tridymite, but when the brick was powdered, it was very difficult to find more! I am of the opinion that, in the majority of our English silica bricks at all events, the conversion in a good useful commercial brick—which is what we are all aiming at—is chiefly to cristobalite. I am referring, of course, to the ground mass of the brick. Speaking petrologically, a silica brick is really a collection of phenocrysts of more or less unconverted quartz imbedded in a glassy matrix in which the original structure of the rock is obliterated. There is great difference of opinion as to what size these phenocrysts should be. On examining these phenocrysts, there is apparently very little conversion in the quartzite or ganister fragments used in the making up of the brick.

You do find, round the edges, traces of conversion, but you never find thorough conversion of the larger grains of quartz into cristobalite, and certainly not into tridymite even in the best-burnt British bricks. I should like again to return our sincere thanks to Mr. Houldsworth and Prof. Cobb, for a most interesting piece of work—work which will live in the memory of those who are investigating this question of silica conversion.

Mr. W. J. Rees:—I should like to join in expressing thanks to the authors for their most interesting paper. We are still somewhat in the dark as to the precise value of the extent of the inversion of quartz in a silica brick. After closely examining numerous examples of unused bricks and the same bricks after use in such a position as the roof of a steel melting furnace, I am not at all clear from the data as to the life and general behaviour of the bricks as to whether any considerable gain is accomplished by obtaining a large amount of inversion of quartz in the bricks for such purposes. It is necessary to examine more closely the view put forward by Dr. H. H. Thomas, that the really important consideration is the concentration in the brick of the greatest possible weight of silica. Unless special care is exercised in the grading of the batch and control of the kiln burning, high temperature burning is likely to increase porosity to an undesirable extent; for many uses the porosity of the silica brick is a determining factor in its durability. For coke-oven use, I have no doubt whatever that a large amount of inversion is absolutely essential; it does not appear to be of major importance as to whether the quartz is inverted to tridymite or cristobalite, the property which counts is the permanent expansion resulting at temperatures from 1,000-1,500°C. The presence in a coke-oven brick of any large proportion of unconverted quartz is undesirable because the further inversion during the life of the brick is likely to set up mechanical stresses which will be detrimental to the life of the ovens.

With regard to the particular crystalline forms of the silica present in used bricks, the observations of the authors seem to be somewhat at variance with many other observations which have been made. I have examined a number of thin sections cut from portions of bricks which have been used in open hearth furnaces and in each case a good deal of tridymite has been present in the dark coloured second layer. In some silica bricks from the roof of a glass melting tank furnace, the inner layer was a glass with much cristobalite, but in the second layer tridymite with a little unchanged quartz was also present. I have also examined a silica brick which had been in the inner portion of the fire-hole of a silica brick-burning kiln for over two years and in this case there is a little cristobalite present, but the bulk of the brick is tridymite, there remaining no unconverted quartz. My own comparative observations on the rate of decrease of true specific

gravity of ganister and Welsh quartzites when heated at temperatures up to 1,500°C. do not compare with those made by the authors. Fine-grained Deepcar ganister decreased in specific gravity a little faster than Bwlchgwyn quartzite; with coarser-grained ganister the rate of inversion was slower than with the fine-grained raw material. These experiments were conducted with prolonged burning and no added bonding material. With Bawtry pebbles the rate of inversion increased slightly with increase of non-siliceous material in the pebbles.

I agree with the authors that the determination of the true specific gravity of the powdered brick is a guide to the possible volume changes in the brick during its use, but only in so far as bricks of about the same lime content are being compared. Comparison of powder densities of bricks with 1·5, 2·0, 3·0 and 5·0 per cent. of lime indicate that with high lime content powder densities as low as 2·30 are compatible with the presence of unchanged quartz.

Dr. A. Scott:—The results obtained by Mr. Houldsworth and Prof. Cobb are exceedingly interesting, especially as they give quantitative data concerning a number of changes which have been discussed in a qualitative fashion to a very considerable extent. Amongst the results are some which do not quite fit in with previous ideas on the subject, and it would be interesting to have an explanation of some of them. For example, in the case of the Meanwood ganister the permanent expansion after the first heating is much greater when no bond is used than when a bond is used. In the latter case, the firing temperature does not seem to have been quite so high. Since in each instance there seems to be no great development of cristobalite, it seems probable that this permanent expansion may be partly due to the quartz crystals having a very high content of gases. Again, it may be noted that the conversion seems to be more rapid in the case of bonded quartzite than in the case of the ganister. As the quartzite is rather more free from non-siliceous materials than the ganister, it might be expected that the latter would convert to a greater extent. It would be interesting to know if any difference in the distribution of the impurities in the two raw materials has been noticed by microscope examination.

With reference to the specific gravity of flint, it might be noted that the lowest figures given in the paper is 2·33. As Dr. Mellor had found that the specific gravity of flint after many firings was as low as 2·22, a figure which has been obtained more recently by some Continental workers, I should like to ask if the writers have found any evidence of the formation of a form of silica with a specific gravity of less than that of either tridymite or cristobalite?

The results obtained from silica bricks which have been used in the roof of a steel furnace do not agree with those previously

described by the present writer. From the examination under the microscope of at least a dozen silica bricks of different makes from the roofs of various steel furnaces, I previously came to the conclusion that the hottest zone of the brick consisted of an aggregate of cristobalite and tridymite together with much magnetite, while in the black zone comparatively large and well developed crystals of tridymite can nearly always be noted. The proportion of cristobalite in the black zone is generally exceedingly small in which case the amount of silicate present is likewise very small, and generally occurs in the form of glass. Most of the iron invariably occurs as ferric oxide and does not seem to react under those particular conditions with the free silica. So far as port bricks are concerned, the ones I examined showed the presence of abundant tridymite in the hot zone of the brick. The structure of port bricks differs very much in different bricks, but, in some cases, the matrix of the hot zone consists of ferrous silicate (fayalite) with well developed tridymite, while the rock fragments are mainly cristobalite, although occasionally unaltered quartz may be noted very close to the hot margin of the brick. The presence of a large amount of tridymite here may be attributed to the action of the ferrous silicates which are relatively fusible. Those observations differ to a very considerable extent from those described in the present paper.

If the Yorkshire quartzitic pebbles were Bunter deposits the amount of conversion seems comparatively high. Of course, in the case of the bricks made up by the author, the amount of bond (3 per cent.), is rather greater than is actually used in practice, hence the results obtained in the case of the "artificial" bricks are scarcely comparable with those obtained from material as usually manufactured.

Another point which may account for some of the results is the question of grain size. Although all the materials were passed through a 20's sieve, there is no reason for assuming that the grading was comparable in different cases. The sieving through a 20's lawn is merely a measure of coarseness and even if the materials were ground in the same pan, it is very probable that the grading of, say, a quartzite, would be very different from that of a ganister. As the degree of conversion depends to a very considerable extent on the grain size of the material, a knowledge of the proportions of the different fractions with diameter less than 20's mesh would have helped in some of the comparisons. It may be noted also that Rebuffat's statement that small amounts of phosphate help the conversion is by no means new. One of the earliest methods of preparing artificial tridymite was to fuse up a mixture of quartz and sodium phosphate or sodium tungstate, and this method has been utilized to a very great extent. Rebuffat, in his paper, makes no mention of the earliest use of sodium phosphate.

With regard to the last statement in the paper regarding a guide for the behaviour of a silica brick, I have found that a quantitative determination under the microscope of the proportion of unconverted quartz is more reliable than the determination of the specific gravity of the brick. In the latter case certain complications are introduced owing to the presence of the calcium silicate and the specific gravity does not always give a true indication of the amount of residual quartz. So far as the former is concerned, there is no difficulty in carrying out quantitative measurements under the microscope and the "test" can be made almost as quickly as a specific gravity determination, apart from the time required to prepare the section.

Mr. MOTTRAM:—I have not had the pleasure of hearing this paper read, but I have had a brief glance at the proof. The thing that struck me rather more than anything else was the absence of any reference in the paper to ganister—real ganister. None of the Sheffield products seem to have been dealt with, and I notice that the Leeds rock—sandstone—is referred to as ganister. I would like to know why this is so, considering that the physical characteristics are entirely different from the ganister as known at Sheffield. Another point is the question of the experiments on flint. Do the results favour the manufacture of silica bricks from flint?

Mr. A. H. MIDDLETON:—I would like to ask the authors whether they intend to carry on their investigations at temperatures over 1,000 degs. C., because I think it is at these temperatures that the work will be of the greatest interest commercially, especially in connection with steel furnaces and cokeovens. Or is there some insuperable difficulty in the way of carrying out experiments at these higher temperatures, due to the fact that the coefficients of expansion are not known?

Mr. HOULDSWORTH:—Our experience with regard to the inversion round the edges of the large quartz particles agrees with the views expressed by Mr. Acton.

With regard to the remarks of Mr. Rees, we did not set out with any pre-conceived idea as to whether a cristobalite or tridymite brick was the better. Nor do we express any opinion on that point even now. All that we have done has been to measure the actual reversible thermal expansion of some commercial bricks and the actual expansion of these bricks after they have been put to various uses. The results of these experiments suggest that the greater part of the unused brick is already cristobalite, and that in the steel furnace any remaining quartz is transformed. The quartz in a silica brick built in the roof of a steel furnace will be converted into the lower density modifications of silica during use, with a resulting permanent expansion and consequent strain, but possibly the results would be less serious in this case than in

a coke oven where one is dealing with a long wall structure.

In answer to the remarks of Dr. Scott, we have throughout the whole of these investigations been surprised at the relative ease with which cristobalite is formed and the difficulty of converting quartz into tridymite. We expected that these results would meet with criticism from some workers. Nevertheless our experience has been that it is far more difficult to obtain tridymite than cristobalite.

Mr. Mottram asked why we selected Meanwood ganister instead of a Sheffield ganister. Naturally, we do not claim any finality for this paper. We have not dealt with all the materials it would be wise or useful to examine, and it would be quite interesting to carry out experiments with a Sheffield ganister. Meanwood ganister was selected because it happens to be a local material, and has been used as a silica refractory. We are advised by Dr. A. Gilligan, of our Geological Department, that we are quite correct in referring to the Meanwood product as a ganister. With regard to Mr. Mottram's question as to the manufacture of silica bricks from flint, there are, as a matter of fact, references in the paper to the behaviour of flint on heating, although I did not read them fully here. Actually, in our experiments, we used flint flour as employed in pottery manufacture, and there is no doubt that the fine degree of grinding had something to do with the flint inverting more rapidly into cristobalite than did the ganister or quartzite. In the case of ganister and the quartzite, we were dealing with materials that had been passed through a 20 mesh sieve. But this is not the whole of the explanation, because although our experiments with specimens prepared from quartzite flour show there is a greater degree of conversion with the finely-powdered material, it is not nearly so great as is obtained with flint. It has been suggested that the presence of slight traces of phosphates might account for the greater facility of conversion of the flint, but no phosphates could be detected in the specimens. I would not like to commit myself to a statement that flint is more suitable than ganister or quartzite for the manufacture of silica bricks. Other properties besides the rate of inversion into the lower density forms of silica have to be considered, but it is undoubtedly true that flint inverts into cristobalite with great ease.

In reply to the remarks of Mr. A. H. Middleton, we should be very pleased to carry out our experiments to a higher temperature than 1,000°C., for we recognise the desirability and the importance of doing so, and we hope in the future to be able to devise some method for this purpose. It will, however, necessitate either a different method, or a preliminary, accurate determination of the coefficient of expansion of some material which can replace the silica glass, for the expansion of this latter material exhibits discontinuities about 1,100°C. We have discussed the

advisability of constructing an apparatus with zirconia replacing the silica glass, but a preliminary investigation would be necessary in order to obtain an accurate value for the coefficient of expansion of zirconia, and what is equally important, to make sure that it possesses no discontinuities in its expansion.

Lt.-Col. C. W. Thomas:—We have certainly had a most interesting paper, and no doubt there will be some members who may like to contribute to the discussion later by a communication in writing.

One point that has been referred to is that of making silica bricks from flint. Right up to the outbreak of the war, I understand that there were silica brick people who used very considerable quantities of French flints in the making up of silica bricks. This is a point upon which Mr. Donald, had he been here, might have liked to say something. As he is not present, and as we have rather exceeded our time limits, I think we shall be compelled now to close the discussion.

The authors in reply to the written contributions of Mr. Rees and Dr. Scott, wrote:—

Mr. Rees' suggestion that a high burning temperature may result in an increased porosity in silica brick is quite true, and is borne out by the results we obtained for Welsh quartzite, but it should be remembered that the same tendency will be experienced when a more lightly burned brick is used at high temperatures—particularly if the heating is rapid. It is, as Mr. Rees states, of the first importance when the bricks are to be used in coke ovens, to transform as much of the quartz as possible into tridymite or cristobalite in the kiln, so that the permanent expansion of the brick is brought about before it is put into use. We think, however, that it is also important to know, as our work has shown, that for ordinary commercial bricks the invertion of the quartz in the kiln takes place into cristobalite, for it is necessary to allow for the large reversible expansion attending the inversion of α–β cristobalite below 300°C. when heating up a long structure like a coke oven wall. We are aware that many observers have described tridymite as found in the second layer of a silica brick after use in a steel furnace and also in bricks after use in coke ovens and kilns. Conclusions based on the examination of thin sections of used bricks by different experimenters, however, are very contradictory. We are of the opinion that it is far more satisfactory to observe the refractive indices of the particles of the powdered brick, and infinitely better to take the actual expansion and contraction. The observations of Mr. Rees on the relative rates of decrease of the specific gravity of Deepcar ganister and Welsh quartzite are interesting, but they do not contradict our own results in any way. We used Meanwood ganister—a material differing geologically and in chemical composition from the Deepcar ganister, as Mr. Mottram emphasised in his remarks,

and no grounds exist for Mr. Rees' implied suggestion that the rates of inversion of Deepcar and Meanwood ganisters are the same. It should also be pointed out that in our experiments a lime bond was used, whereas Mr. Rees was dealing with raw materials without added lime, and different results might very well be obtained under these different conditions. The presence of much lime in a silica brick will affect its specific gravity. We should expect, although we have made no experiments on this point as yet, that apart from any increased transformation of the quartz which may be produced, the effect of a high lime bond would tend to raise the specific gravity of the brick, and not to lower it as suggested by Mr. Rees. In any case it would not seem that very great changes in specific gravity would be produced even if 5% of lime were present.

Lime in the presence of large excess of silica forms $CaO.SiO_2$,* which has a density of 2·8 to 2·9. Assuming the bulk of the CaO to react to give $CaO.SiO_2$ (wollostonite), we should have with 5% of added lime about 10% of $CaO.SiO_2$, and with 2% of CaO about 4% wollostonite. Taking the densities of cristobalite, quartz, and $CaO.SiO_2$ as 2·33, 2·65, and 2·8, we should get the following figures for the densities of the silica brick, assuming, as our results and those of D. W. Ross indicate, that the bulk of the inversion of quartz in a commercial brick has been to cristobalite.

	With 5% CaO (10% $CaO{\cdot}SiO_2$)		With 2% CaO. (4% $CaO{\cdot}SiO_2$)	
90% quartz	..	2·66	96% quartz ..	2·655
50% quartz	..	2·52	50% quartz ..	2·50
0% quartz	..	2·37	0% quartz ..	2·345

The maximum difference in density in the two cases is ·025 which corresponds with an error of less than 10% in the deduction of the quantity of quartz inverted. It is customary when examining a silica brick to determine its fusibility, and a high lime content would depress its cone melting point, the softening temperature being about 1,600°C. with 6% of lime.

Dr. Scott comments on the difference (0·1%) between the permanent expansion found for Meanwood ganister with and without lime bond, after firing to 1,000°C. It should be remembered that the whole of this expansion is due to porosity changes of the material resulting from rearrangement of the constituent particles. The degree to which this occurs may conceivably be affected by the presence of the bond.

With regard to the relative rates of transformation of Meanwood ganister, quartzite, and flint, we are of opinion that the difference in the distribution of impurities is of less importance than the crystalline character of the raw material, flint with its very fine crystals embedded in colloidal silica transforming more rapidly than the other materials examined. We have not found

*Cobb, J. *Soc. Chem. Ind.*, **29**, 252, 1910.

any evidence in our experiments of a crystalline form of silica with a specific gravity less than that of tridymite or cristobalite.

Some of the conclusions reached by Dr. Scott after the examination of thin sections of used bricks are by no means generally accepted as, for example, his statement (TRANS., **17**, p. 468) that "the evidence of these bricks tends to confirm the idea that tridymite is the stable form of silica up to at least 1,550°C." Dr. Scott reminds us that he considers that the hottest zone of a brick from the roof of a steel furnace to consist of an aggregate of cristobalite and tridymite, together with much magnetite. In Fig. 15 (curve *A*) of this paper we give the *quantitative* results obtained for the thermal expansion of the hottest zone of the brick which had been used for some months in the roof of a steel furnace. It will be seen that a very large, reversible thermal expansion (amounting to about 0·7% and corresponding with about a 70% cristobalite content) was observed between 240°-280°C. In view of the presence of large amounts of magnetite and silicates in this zone, it is obvious that only small amounts of tridymite can be present. The expansion observed for the black layer of this brick (Fig. 15, Curve *B*) from 15-250°C. is about $\frac{5}{6}$ths of that of the unused brick, and cannot be explained on Dr. Scott's view that it contains only exceedingly small amounts of cristobalite. Similarly the expansion of a brick after use in a gas port of a steel furnace (Fig. 12, Curve *C*), indicates without doubt the presence of a very large amount of cristobalite. The large reversible expansion associated with the transformation of α to β cristobalite supplies, in our opinion, far more conclusive evidence of the presence of large amounts of cristobalite than can be obtained from any examination of thin section. We should, however, welcome warmly the opportunity of testing one of these bricks which the observations of Dr. Scott or any other worker indicate to consist largely of tridymite. As C. N. Fenner has pointed out, owing to the fine grained character in which tridymite and cristobalite commonly occur in silica bricks, the likeness between them is so great that identification is unusually difficult, and he suggests that the most easily determinable distinctive difference, apart from their volume changes on heating, is that of their refractive indices, which we have freely used. It is not possible to explain the expansion curves we obtained for these bricks after use in steel furnaces or coke ovens on any other assumption than that they consist largely of cristobalite. This does not mean that we doubt the accuracy of Dr. Scott's own observations. But so many workers have reached mutually contradictory conclusions as the result of microscopic examinations that great bewilderment has been created as to what does happen to a silica brick in use. Probably as C. N. Fenner suggests* the fluctuating temperatures which occur in furnaces make it

* *J. Soc. Glass Tech.*, **3**, 116, 1919.

difficult to predict how silica will behave under these varying conditions, so that sometimes tridymite and sometimes cristobalite may be produced.

We must point out to Dr. Scott that the 3% of bond we used was plaster of Paris, so that he is not correct in asserting that we used more lime in preparing our test pieces than is employed in industrial practice. Further, Dr. Scott will note that we prepared no test pieces from Yorkshire (Bawtry) quartzite pebbles. The specimen we examined was cut from an actual commercial silica brick made from these pebbles and neither expansion experiments nor microscopic examination of thin sections revealed any unconverted quartz.

We quite agree with Dr. Scott that it would have been more useful if the materials passing through the 20 mesh sieve had been further graded.

We consider that a determination of the specific gravity of a silica brick is simpler and quicker than the preparation and examination of a thin section, and gives satisfactory information as to the subsequent expansion of the brick in use, although, of course, not with the precision which attains to actual measurements in the expansion apparatus. D. W. Ross (*Tech. Paper*, 116, *Bureau of Standards*, p. 83), as a result of his extensive examination of American bricks, concludes that the specific gravity of a brick clearly denotes the degree of burning which it has received in manufacture and, in conjunction with the porosity, indicates approximately how much the brick will expand in use.

Summarising, (1) this work was undertaken with the object of supplying quantitative data of the actual reversible expansion on heating of silica materials and products after various preliminary heat treatments—data which are quite independent of the interpretations of these results in terms of the various crystallographic forms of silica, interesting though these may be. Our results have, therefore, been usually stated in two forms, the one a description of dimensional alterations, the other in terms of crystallographic structure, the latter being checked as far as possible by parallel determinations of specific gravity and refractive index. The accuracy of the first method of stating the results depends solely upon the accuracy of the measurements we made, but that of the second depends on the correctness of the properties attributed to various forms of silica by previous workers. (2) It is important, using crystallographic terms, to convert as much as possible of the quartz of a silica brick into cristobalite (or tridymite) in the kiln, so that strains in furnace structures, etc., due to permanent expansion after walling in the furnace, may be reduced as much as possible. Our experiments show that in unused commercial silica bricks the inversion of the quartz has been chiefly to cristobalite, and that very little tridymite occurs. The experiments of McDowell and of Ross agree with this conclusion. McDowell

found only 4% of tridymite in a brick made from Medina quartzite, while Ross reported only 2% of tridymite in a silica brick of German origin. We have not examined sufficient used silica bricks to be dogmatic as to the changes occurring during use. All that we can say is that we have reported faithfully the results obtained with such bricks as we have examined. The magnitude of the expansion observed from 15-250°C. for the silica bricks we tested after use in a steel furnace or coke oven indicates very forcibly that bricks consist largely of cristobalite. It is possible that the varying conditions in different furnaces may be the cause of some investigators finding cristobalite and others tridymite as the form of silica present in bricks which have been heated for long periods to high temperatures.

XVI.—Description of a Tunnel Kiln in Czecho-Slovakia.

By H. Barkby.

WHEN I first passed through the pottery district of Czecho-Slovakia, and remembered that efficiency and thoroughness were always connected with Germany and her satellites, I was compelled to question if they spelled those two words as "Dirt" and "Smoke", for surely our own black country is a beautiful place when compared with Chodau, Poschetyau, Altrohlau and the other pottery towns.

Small wonder that, when I first heard of a tunnel kiln in a district so full of smoke which was firing porcelain at Cone 14, I took it with a pinch of salt and decided to pay it a visit if possible. This I was fortunate enough to do and found it to be the Faugeron system. I was surprised to see the excellent porcelain they were obtaining.

The managers who took me over the factory endeavoured to give me all details they could, but as they could only speak about as much English as I could German, it became at times very difficult to understand one another. However, I obtained some excellent notes from my visit and will do my best to give a clear idea of the construction and working principles. In some cases my figures are those given to me and in others what I worked out on the spot. The diagrams I have had to draw from memory, and therefore I do not wish anyone to go away with the idea that they are accurate; rather do I use them as a means of making myself clear. Before I proceed with the description of the kiln, I may mention that the composition of their body as given to me was: china clay, 40; flint, 30; spar, 30. With regard to their glaze, I had to be content with the information that it is composed of the body mixture plus lime, part of the china clay being first calcined. The clay ware is fired first to about 950° in a tunnel kiln similar to the one I am about to describe, after which it is dipped and both body and glaze matured at Cone 14.

In figure 1, I show a diagram to give a general idea of the principle of the oven before going into details. The total length of the oven is 60 metres (196 ft.), with a fire place on either side at the middle. The width of the inside is about 1·25 metres (4 ft.), and the length from the rails to the vault roughly 3 metres (10 ft.). Below the level of the rails in an inspection passage large enough

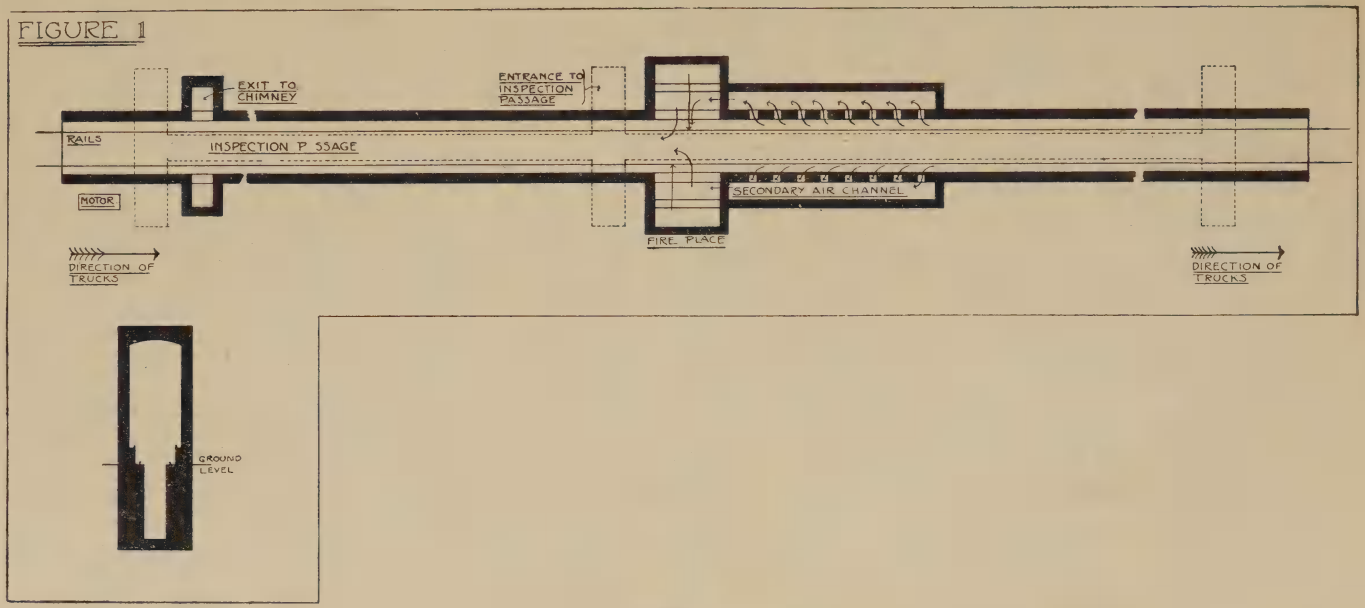


FIGURE 1
EXIT TO CHIMNEY
ENTRANCE TO INSPECTION PASSAGE
RAILS
INSPECTION PASSAGE
MOTOR
SECONDARY AIR CHANNEL
FIRE PLACE
DIRECTION OF TRUCKS
DIRECTION OF TRUCKS
GROUND LEVEL

Fig. 1

for a man to walk down. It was almost the full length of the tunnel, with entrances at several convenient points to enable the attendants to pass from one side to the other without having to walk right round the tunnel. At the entrance to the tunnel is situated the motor which drives the fan for drawing gases to the chimney and also which pushes the trucks through. On the exit side of the fire-places will be noticed two secondary air channels which conduct the heated air from the cooling goods to the fire places. On the inside of the tunnel, I was told there are a series of pipes and baffles which carry the air from the cooling goods into these passages. As I could not actually see how they are arranged I have indicated their presence by gaps in the tunnel walls. Near to the fire-places are dampers to regulate the supply.

Leaving the tunnel for a little while, I will describe the construction of the trucks which measure 2 metres (6·5 ft.) long by 1·25 metres (4 ft.) wide. In Figure 2 (Diagram A), I give an end

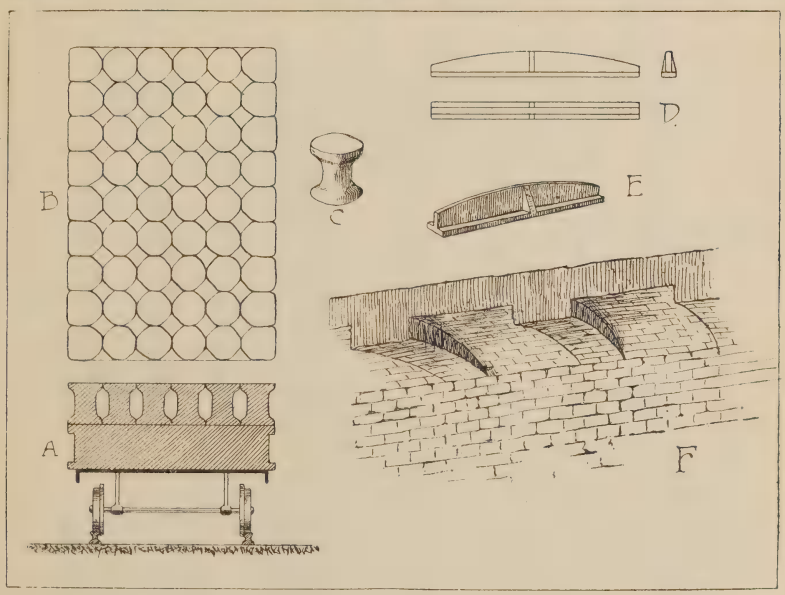


Fig. 2

elevation of a truck. Immediately above the wheels is a platform made by strong sheets of iron with the sides turned down for a couple or three inches. These iron lips are for the purpose of the sand seal. On this iron platform is built a solid bed of fire-clay bricks approximately 9 inches thick, to protect the iron and to insulate the oven. A groove runs along each side of this brick work and into this fits a rib which runs the whole length of the

tunnel. Above this solid bed of fireclay bricks are arranged fireclay studs similar in shape to a cotton bobbin, only much larger, being about 10 inches high. The perspective sketch, figure 2 (Diagram C), gives a clear idea of the shape. When these studs are placed side by side it will be seen that flues are formed both lengthways and crossways of the truck with gaps in the upper surface (see plan Figure 2, Diagram B). The studs on either side are a little different in shape on the upper surface, so as to give a fairly straight edge to the truck. On this layer of studs are placed the saggars, containing the ware to be fired, to a height of two metres (6·5 ft.) and then above and across them are put fireclay baffles of the shape shown in Figure 2 (Diagrams D and E). This completes the loading of the truck, but before it is sent into the tunnel it is passed under a loading gauge similar to those used on the railway to see if it is over or under loaded. I have drawn diagrammatically a loaded truck which I think will clearly explain the construction and loading (Figure 3).

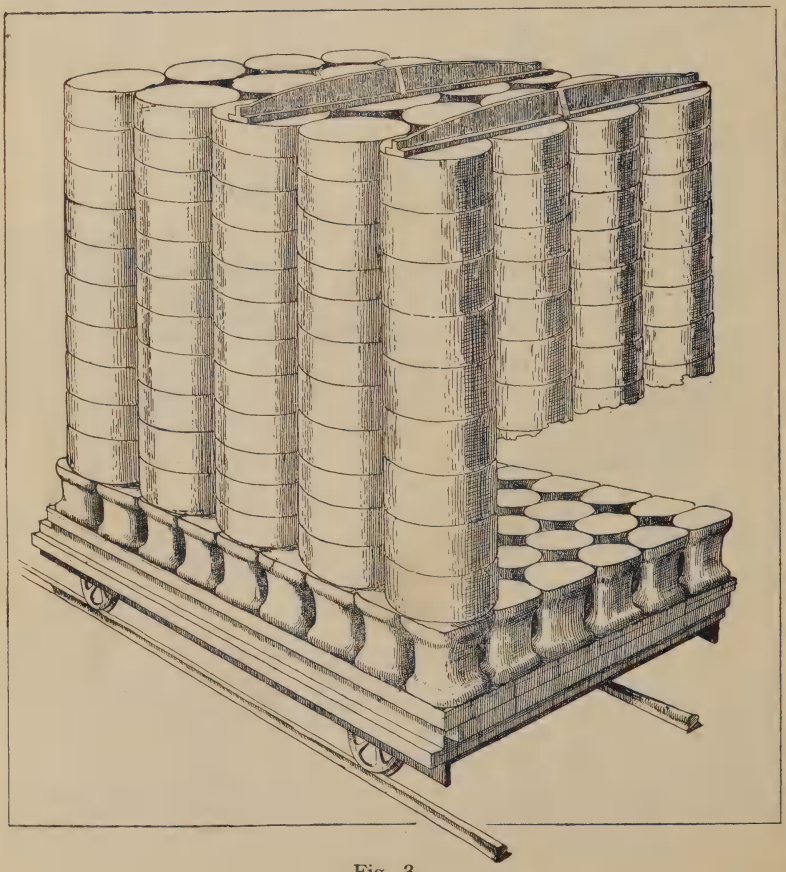


Fig. 3.

Before following the loaded truck into the tunnel, I will explain the formation of the roof of the tunnel. This can best be done by means of the perspective sketch Figure 2 (Diagram F.). The vaulting of the roof corresponds to the curve of the fireclay baffle which fits across the saggars and continues so for some distance along the tunnel. It then rises for a short distance before returning to its original form. This rising and falling of the roof continues along the tunnel for some distance past the firing zone, but the roof then remains the same as at the entrance.

Now we will follow the loaded truck into the tunnel. The workmen push it into the tunnel up to the previous truck, where it becomes engaged in a catch connected with the driving motor, after which it is slowly driven along at about an inch per minute. The two iron lips also enter the two grooves or gutters which are filled with grog and so seal up the tunnel from below, and at the same time prevent the heat reaching the under carriage (See Fig. 4). Although air locks are provided at the entrance and exit, they were not

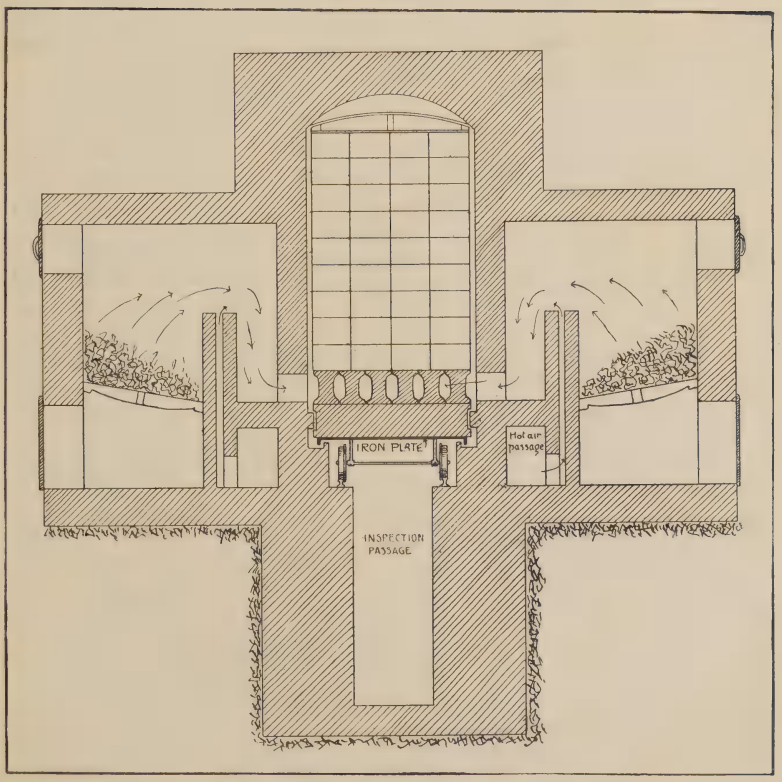


Fig. 4.

using them at the time of my visit. I was told that the saggars and fireclay baffles fit so close to the walls and roof of the tunnel that they could do without them. As the truck moves along, it passes the chimney entrance and then onwards to the firing zone; it is then in contact with the hot gases and so gradually becomes warmer and warmer until it arrives at the hottest part of the tunnel.

Figure 4 is a cross section at the fireplaces with a loaded truck in position. The firing system is semi-gas. There is a fire box behind which is a split bag, up which comes the pre-heated secondary air from the cooling goods as indicated earlier. This air passes along with the combustion gases and partial mixing takes place in the chamber between the bag and tunnel wall. It then passes into the tunnel on a level with the flues of the truck. After passing into these flues the gases travel up the saggars. Now, turning to the longitudinal section Figure 5, we can follow the gases along the tunnel in the opposite direction to which the trucks are moving. The gases, having travelled up the saggars, proceed over them until they meet the fireclay baffle B which is immediately under the drop arch A, and are turned down the saggars into the flues of the truck, only to rise again on reaching the saggars past the drop-arch and baffle. This ascending and descending of the hot gases is assisted by the fact that hot gases rise and cold ones fall. The hot gases in passing up the saggars lose some of their heat and tend to fall and give place to the hotter gases behind, but in travelling down the tunnel they come to a point in the flues where they are hotter than the goods above them and ascend again. This cycle continues all the way along the tunnel, the goods becoming warmer and the gases cooler until they are drawn out into the chimney flues. I have indicated the path of the gases by arrows in the sketch. As the goods are moving forward all the time, it will be seen that at one period the gases will be travelling upwards in those particular bungs on the entrance side of the drop-arches and then as those bungs move forward the direction will be reversed in them and so this change of direction goes on alternating all the way through the heating and cooling of the goods. This helps materially in maintaining an even rise and fall in temperature. I was informed that the gases, on leaving the tunnel, are at a temperature not higher than 300 to 350° and are used for heating greenhouses and store rooms before going into the chimney. The goods as they leave the tunnel are cool enough to handle.

I made a trip along the inspection passage, and was surprised to find I could comfortably place my hand on the wheels and rails while under the fire zone. The seals were easily got at, but from what I saw they required no attention. They use grog as being cheaper than sand and consider it just as efficient. They have a recording pyrometer in continual use, but the fire-man prefers to rely on his trials which he draws exactly the same as we do in the round ovens. I saw a truck unloaded immediately on leaving

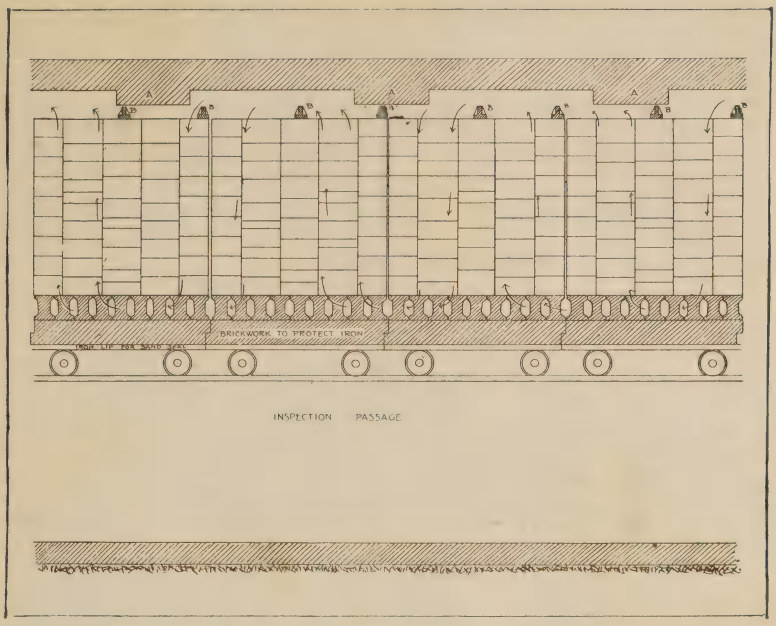


Fig. 5.

the tunnel, and saw no dunting and only two cracked saggars. As one truck is unloaded the saggars are passed on to the placers, who fill and place them on the next truck to go into the oven. This saves a great deal of handling and therefore wear and tear on the saggars. While I am speaking about saggars, I will mention that their saggars are thinner than those in common use here and are machine made. The underneath surface of the saggar is concave, which, they claim, gives strength with lightness. The tunnel holds 30 trucks, and a truck travels from one end to the other is 36 hours. I calculate that in 24 hours the output is almost equal to one of our 18-foot round ovens. The coal consumption per day is about $2\frac{1}{2}$ to 3 tons, but as they use their local brown coal, I think we should find it far less in this district. As they are firing porcelain, it is necessary to have a reducing atmosphere, and they "smoke" for two thirds of the distance from the fire places to the entrance. Repairs are very small. I was told that only once a year is it necessary to attend to the fire boxes. The under carriages which were put into use 12–16 years ago are still running without having been repaired.

In a letter I received a few weeks ago from the builders, they claim for their oven as compared with the old fashioned type :— (1) Over 50% saving in fuel ; (2) 30 to 50% saving in saggars ; (3) Reduction in the amount of dunting ; (4) Temperature under

complete control; (5) The work is rendered easier and cleaner for the workmen; (6) Very little smoke.

The following kilns are in use on the Continent:—For earthenware industry 9 kilns; for porcelain 7 kilns, with 3 being built; for firebricks 2 kilns; for wall tiles 1 kiln, with 1 being built. With regard to the cost of building, I am sorry to say I cannot give any figures owing to the continual fluctuation of the mark.

In conclusion, I may say that anyone who is going to the Continent may see any of the kilns, as the builders are only too anxious to assist interested persons.

DISCUSSION.

Mr. W. LINDLEY:—I received a letter this evening from my friends abroad, whose tunnel kiln I described to you some time ago, informing me that they have just had their annual cleanout. Work has been stopped, in consequence, for 12 days. They only have occasion to stop 12 days each year. It was surprising, they tell me, what little damage had been done during the year to the firing zone.

With regard to the saggars, I may say that our experience was very different from Mr. Barkby's. We found that the saggars deteriorated very much. Fully half the saggars were cracked in the oven that I saw. The oven described by Mr. Barkby was built by the same firm, but in this particular oven there were no baffle arrangements. The arrangement described baffles me too. How they can possibly rear up 8-10 saggars to a baffle and still have a seal on the bottom of the tunnel I cannot quite understand, because saggars are not quite so true as all that. There must be some passage provided, or there would be a jam sooner or later.

My friends appear to be very pleased with the oven that they have, but they certainly experience a greater deterioration of saggars than was apparently the case in the kiln which Mr. Barkby inspected. However, in this particular kiln they fire with wood, which may account in some way for the greater destruction of the saggars.

Mr. BARKBY:—I think the kiln that Mr. Lindley saw was much smaller than the one I have described. I cannot say whether it was built later or not.

Mr. LINDLEY:—The kiln I described was built about 12-14 years ago.

Mr. J. H. MARLOW:—Can Mr. Barkby give us any information as to why the bottom saggars on the truck are left empty?

Mr. BARKBY:—No, I am afraid I cannot, unless it is for the reason that the bottom saggars get the full force of the gases as they are passing the fire boxes. I may say that they fire porcelain, and they only place one plate in a saggar, which is a rather different

proposition from the practice here. They do not prop anything if they can avoid it. The result is that their saggars are very low; they are more like kiln boxes. In the case of saucers, they are placed only one high. We, in the Potteries, cockle them up 10-12 high. There is not much waste, seeing that the empty saggars are only one plate deep.

Mr. MARLOW:—Am I right in assuming that combustion takes place actually in the tunnel, and that the reason for leaving the bottom saggar open is that they are afraid of the flash which would naturally be experienced by contact with gases that were not properly combusted in the combustion stage?

Mr. BARKBY:—I believe that the explanation that was given to me was that the bottom saggar gets the full force of the gas.

Mr. LINDLEY:—In the kiln which I described, the saggars were placed with general earthenware plates, 20 high, and cups in the usual way. The saggars were placed just the same as ours for the beehive ovens. Consequently, they would have a greater weight in them, and perhaps that would account for the greater breakage in saggars to which I referred. Saggars that are used with only one piece in them naturally ought to last considerably longer.

Mr. BARKBY:—In connection with this porcelain, the body and glaze are matured together at cone 14. The firm has another kiln in which they just biscuit at 950-1,000 degs. C. I was not at the works sufficiently long to verify everything that I have put before you. A lot of the points in the paper simply recount what I was told.

Mr. MARLOW:—Can Mr. Barkby tell us what tonnage of ware is produced by this particular kiln per ton of coal used per 24 hours?

Mr. BARKBY:—I am afraid I cannot. I calculated that the output in 24 hours is roughly equal to the output of one of our 18 ft. round ovens. The coal consumption per day they gave me as being $2\frac{1}{2}$-3 tons, but the coal is much inferior to ours.

Mr. MARLOW:—How many saggars do they get on each truck?

Mr. BARKBY:—I did not count them. The saggars are placed to a height of about six feet.

Mr. MARLOW:—If one article only is placed in each saggar, and the trucks travel at an inch per minute, I hardly think they would get that quantity of ware in 24 hours loaded in the manner you describe. Then again, so far as that inch clearance which you referred to is concerned, I think anyone who has had experience of a tunnel oven will say that that is ridiculous. They would be asking for trouble, and would very soon get it, if they worked so near as that. I do it with four inches, and get perfect circulation. My gases work through in concertina fashion, and I succeed

in getting the same heat at the bottom as I do at the top.

I may say that the Faugeron is the nearest to my tunnel that I know of, and I believe that the kiln described by Mr. Barkby is a vast improvement on the one that I have seen. I have had my tunnel oven running a year and seven months, and I can tell you that there is not one brick that needs repair. There is not a brick to touch. The bricks are in as good condition to-day as the day they were put in, and I believe they will be in 15 years from now, in spite of the fact that I have been as high as 1,300 degs. C. The difference between my kiln and the one described consists in the fact that I have a combustion chamber outside the kiln in which I get my first combustion. I also have chambers inside, not open to the fire, where I get secondary combustion, the products of which are perfectly delivered to the goods in the kiln. I have just finished another kiln for biscuit, which is 300 feet long by 8-9 ft. high, and this will carry 72 saggars on a truck. I hope that before many weeks are over I shall be able to prove to you that I have a kiln that is worthy of any potter in the district.

Mr. WILLIAMSON:—The kiln which has been described by Mr. Barkby is no doubt a very interesting one, but there are many others of this description that have been built. One of these is at Sarreguemines.

I think Sir Arthur Duckham is perfectly right in his remarks. I fail to see myself how the gases can possibly take the course which it is claimed they take. I am inclined to think that it is more a theory than an actual fact. Most people who have had experience with tunnel ovens know very well that it is extremely difficult to control the direction of the gases. The types of kilns on the market are now very varied, and the various types embody some very good ideas. No doubt the kiln that Mr. Marlow has is a good and very simple kiln, but, like everything else, it has its faults, and possibly it is not quite as perfect as perhaps Mr. Marlow would like us to believe.

I understand that the object of this meeting to-night is to discuss the advantages and disadvantages of the particular kiln that Mr. Barkby has described to us, and to compare it with the chamber kilns of the old types that are still being largely used in this district. I should be very glad indeed if some member present who has had experience of the chamber type of kiln would give us the benefit of that experience. I feel that the chamber kiln is a very good one, but, like the others, it has its disadvantages. At the same time, I believe that for certain classes of ware and for large outputs we shall be hearing much more about it in the future. I am sorry that up to now we have had so much of tunnel firing that we have not had an opportunity of listening to the other side of the question. Personally, I should be very glad, and I am sure that the members of the Society as a whole would be greatly interested, if either Mr. Shaw or Dean, Hetherington & Co., or

anyone else who has had experience of the working and design of chamber kilns, would come forward and give us the benefit of their views.

Coming to the question of the respective merits of the two types of kilns, if it is accepted for the sake of argument that gas-firing is the ideal to be aimed at, there are two ways in which continuous firing can be carried out. The one is where the heat is mobile and the goods are stationary: the other is where the heat is stationary and the goods are mobile. So far as I can see, the idea should be to keep the heat local and travel the goods. But I am not at all satisfied that this is quite perfect, and I would be very glad indeed to have the experience of people who have tried either of the methods mentioned.

There is also another question which is a very interesting one, and which I think has not been brought forward quite as prominently as it ought to be, and that is the question of the atmosphere of the kiln. I think it is pretty well accepted that whilst the majority of clay products should enjoy an oxidizing atmosphere, we know also that there are some which require a reducing atmosphere, and others which require an oxidizing atmosphere at the commencement and a reducing atmosphere at the finish. Now it occurs to me that the ideal kiln would be one in which the atmosphere in the early stages of the firing is oxidizing, and in the final stages either oxidizing or reducing as the case may be. I have in mind now a kiln which has been working for several months firing electrical porcelain to a temperature of cone 14, and giving a soaking period of 7 hours, where the atmosphere in the early stages is perfectly oxidizing and in the final stages is reducing. The atmosphere can be varied at will to give any degree of reduction that is necessary. Some of the insulators that have been fired in this particular kiln have been tested to very high voltages. If I were to mention the figure, there might be some persons present who would be disposed to question it. But the figure is certainly very much higher than one is accustomed to hear of in this country. The kiln has been pronounced by experts in insulators to be the finest kiln that has yet been built for the firing of this particular class of ware. I am not disposed to say that this particular kiln is the best kiln for all purposes, but I think there are gentlemen in this room who have had experience of the kiln which I have in mind who will bear out my statement. I will not say any more at the moment, except to ask our Secretary if he will invite some member of this Society, or an outsider who has had experience of the chamber kiln, to come forward and enlighten us a little. Personally, I have a great regard for the chamber kiln. I saw one working in Germany about two years ago, and as far as I could see, this kiln was ideal for the particular class of ware that it was firing.

Sir ARTHUR DUCKHAM (communicated):—I have read with

interest the paper by Mr. Barkby on the Faugeron Kiln. Several points are of considerable interest:—

(1). That the brickwork of the kiln can be kept in such true alignment that bye-passing does not occur between the side of the saggars and the walls of the kiln. I should say that it would be necessary to have at least 1″ clearance between the saggars and the walls of the kiln on each side, and this clearance would give a flue area of 10′ 0″ (120″)×2″ —*i.e.*, 240 sq. inches—for the gases to bye-pass along, this taking no account of the 1″ clearance which will presumably be necessary also over the sectional baffles on top of the saggars.

(2). I cannot conceive the change of flow mentioned on page 283. It is one of the most difficult things when you have set up a distinct flow of any fluid to reverse that flow, unless considerable power is applied.

(3). Is there any baffling of the bottom flue work formed by the stools or studs? If there is not any baffling here, I should say there was a likelihood of gases passing right along the longitudinal flues formed in the studs and so upsetting the very pretty reversing flow claimed.

(4). Why does the secondary air follow the somewhat tortuous paths of the secondary air flues, instead of passing along the sides of the kiln and through the bottom longitudinal flues?

It is very interesting to know that the under-side of the carriage is kept so cool. This bears out my own experience.

I consider that one of the great advantages of the kiln is that it has an outside combustion chamber which naturally gives much more even heating and prevents flashing of the goods and damage to the saggars by flame action on the same.

I am working out the capacity of the oven, which is of considerable interest, but personally, I do not feel that the actual flow of the gases as claimed by the kiln makers takes place.

Mr. BARKBY:—In reply to Sir Arthur Duckham, I may point out that: (1). The users of the kiln in Czecho-Slovakia emphasized the necessity of using only the very best of materials and workmanship in the building of the tunnel kiln. Speaking from memory, I should say the clearance space between the saggars and kiln walls was over one inch, and therefore there must be a fair amount of bye-passing of the gases.

(2). The flow of the gases does not change. It is only the trucks which move through rising and falling streams of gases as will be seen by referring to Figure 5.

(3). There are no baffles in the bottom flues as they would interfere with the flow of gases which is mainly set up by the drop arches which are stationary.

(4). If all the secondary air was supplied only by the longitudinal flues and sides of the kiln, it would be very difficult to control the quality of the atmospheres and this is very essential where porcelain is to be fired.

XVII.—The Adsorption and Dissolution of Gases by Silicates—"Spit-Out."

By Bernard Moore and J. W. Mellor.

INTRODUCTION TO NEW EDITION.

WE published a paper on the spitting of glazes in our Transactions in 1907, and the following year there was a discussion on the paper opened by the late Mr. W. Jackson. The paper contained a few new ideas on the subject, and, as might have been anticipated from the native inertia of the human mind, there was some opposition to the views which we propounded. In the discussion, one of us expressed the view:

> For three years the new ideas as to the cause of spitting will be dubbed theoretical nonsense; after that a few will begin to admit that there might be something in the theory; after that, many will believe that they knew all about it long before our paper was laid before the Society.

The journal with the paper is out of print, and it has been represented to the Council of the Society that the paper ought to be reprinted. It was further suggested that the original paper might be also revised and brought up to date, and then serve as a basis for another discussion on the subject. The prediction which we made has been amply justified, and in critically reading over the old paper, we have very little new matter to add. Anything we can now say is but confirmatory. This, however, makes us rightly suspicious of pet theories because they can so readily and so quickly become tyrannical masters instead of useful servants. Such a transition can be prevented only by the purging effects of intelligent criticism. We therefore welcomed the announcement recently made that Mr. Miles would explode the views which we have expounded. We were astonished to find that Mr. Miles' main theory was to advocate one of the views of spitting which we had strongly emphasized in our previous paper; and, judging from the fact that he did not mention our previous work on the subject, it is doubtful if he has more than heard of our views except by heresay. This inference is confirmed by his remarks on a second cause of spitting which we put forward—namely, the carbon hypothesis—which he rejects; at any rate, we are justified in asking for evidence that he does understand it, otherwise, he has no right to express his opinion on the subject. The same remark applied to J. Gater's statement in his *Practical Treatise on the Manufacture of Pottery* (Derby, 132, 1921):

> It has been suggested that sometimes the biscuit ware is charged with gases which become eliminated on passing through the enamel kiln, but there is no practical proof that this is the cause; in fact, if it were so, one is tempted to ask why the gases were not eliminated during the process of glost firing. It is the writer's opinion that it is a modified form of blistering caused by an irritation of the enamel, which would be avoided if the temperature of the kiln was gradually increased.

It may seem an easy way of evading a difficulty, for us to deny that the propounder understands what he is talking about; but there seems nothing else to be done when well-established facts are denied *ex-cathedra*, and the fundamental principles of science are ignored. We must confess that after fifteen years' experience with the hypothesis we put forward in 1907, the evidence showing the body to be one of the most fruitful sources of spit-out has been continuously accumulating and now we both believe that it is overwhelming.

1—*Introduction*.

"Spit-out" is one of a number of "mysterious" faults which occur in the manufacture of pottery, and the loss which "spitting" has occasioned, if translated into £. s. d., must be enormous. Glazes when fired in the enamel kiln between 700° and 900° appear to develop bubbles of gas, which burst at the surface of the glaze. The appearance of a typical "spit" is shown magnified 30 times at *a* (Fig. 1); although we have plenty of examples of "spits" which reach from the surface of the glaze right down to the body. It will be obvious that the bubbles must contain gases or vapours of some kind. The broken surface to the right of *a*, Fig. 1, is a section through three "spits" close together.

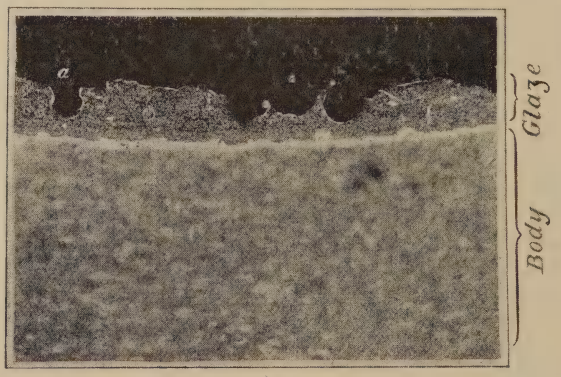


Fig. 1.—Section through a typical "spit."

So far as our knowledge goes, no clear explanation of the phenomenon has hitherto been published, although attempts have been made by M. Solon (*Pot. Gaz.* **31**, 69, 1906), and R. G. Cowan

(*Trans. Amer. Cer. Soc.*, **9**, 493, 1907); Jno. Miles (TRANS., **21**, 208, 1922); there is also a discussion on the subject in the TRANS., **3**, 30, 1904.

2.—*Sulphuric Acid Theory of Spitting.*

A one time popular theory of spitting was based on Seger's observation (H. A. Seger, *Gesammelte Schriften*, Berlin, 509, 1896; *Amer. translation*, Easton, Pa., **2**, 646, 1902; W. Jackson, TRANS., **3**, 30, 1904):—

"A bisilicate glaze saturated with sulphates contains 4 per cent. of sulphur trioxide in solution, whereas a trisilicate, under similar conditions, contains only 2 per cent. Hence it follows that if a bisilicate, saturated with sulphates, dissolves more silica from the body, it can give up 2 per cent. of sulphur trioxide. This important fact explains many phenomena associated with the blisteriug. I am quite unable to find anything in the ordinary constituents of a glaze—alkalies, alumina, silica, lead, calcium, and boric oxides—which can give rise to the phenomenon."

This means that the greater the acidity of the glaze, the less its "carrying capacity" for sulphates. When "spitting" occurs in a hard-fired enamel kiln it is assumed:—

(1) That the glaze is saturated with sulphates in the glost oven;

(2) That the glaze dissolves silica from the body presumably in the enamel kiln;

(3) That the sulphur trioxide is ejected from the glaze in the form of bubbles of sulphur dioxide, sulphur trioxide, and oxygen; and

(4) That those bubbles near the surface of the glaze burst in the enamel kiln.*

These highly ingenious suppositions are an attempt to apply Seger's theory of blistering of glazes to "spitting" in the enamel kiln. The hydrocarbon gases, normally present in the atmosphere of imperfectly ventilated kilns, may reduce the more stable sulphates to less stable sulphites. The latter readily decompose at comparatively low temperatures. At any rate, the phenomenon is easily imitated. Glazes rich in sulphates can be made to blister and spit when fired in an atmosphere containing hydrocarbon gases (*e.g.*, coal-gas).

The sulphuric acid theory of spitting is quite inadequate when applied to spitting generally. Indeed, it is impossible to devise a general theory to cover the known facts, because the phenomenon may be produced in different ways.

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*It has been further assumed that the "spitting" of old ware is due to the fact that the sulphur oxide imprisoned in the bubbles has eroded and thinned the glaze between the bubble and the surface, and that this facilitates the subsequent bursting of the bubbles. But this hypothesis is not attractive.

3.—*Some Effects of the Volatilization of "Lead" from Glazes.*

Before leaving the "sulphuric acid theory" of spitting it may be of some interest to point out that when "lead" volatilizes from the surface of a glaze saturated with sulphates, it follows that sulphur trioxide must be given off because the glaze is becoming more acidic. This corollary from Seger's observation throws some light upon :—

(*a*) The blistering of glazes in the vicinity of dry thimbles, which, by taking up the vapours given off from the glazes, are notorious for accelerating the rate of volatilization of "lead," etc., from the surface of glazes in their vicinity.

(*b*) The "matting" of glazes in the enamel kiln, particularly that type which sometimes occurs near the quarries.

(*c*) The "matting" of "curtained glazes," and the dry edges of glazed tiles. *En passant*, it may also be noted that these parts are more likely to be saturated with sulphates, since any soluble sulphates in body or glaze will have a tendency to accumulate at the edges on drying.

(*d*) The breaking up of the surface of a glaze which is one source of that defect known as "silver marking."

(*e*) The tendency of "fritted lead" glazes to blister more readily than "raw lead" glazes in the glost oven. In "fritted glazes" the whole of the lead is usually introduced as a bisilicate, which, according to Seger, may hold 4 per cent. of sulphates in solution. As the bisilicate reacts with the other constituents it becomes more and more acidic, and, accordingly, becomes capable of holding less and less sulphates in solution as the glaze approaches its maturing point. With "raw lead" glazes the carrying capacity for sulphates is, on the contrary, always increasing until the glaze reaches its maturing point. It is also interesting to note that the fault indicated under (*c*) is more prevalent with "fritted lead" glazes than with "raw lead" glazes.

4.—*The Viscosity of Glazes in the Enamel Kiln.*

Although the glaze in the enamel kiln is 200°-300° below the so-called maturing temperature of the glaze in the glost oven, yet it is sufficiently mobile to permit the movement of the bubbles in its mass. The explanation turns on the fact that glazes, like glasses, are really supercooled liquids. They seldom pass through a perceptible change of state during cooling. Consequently we cannot discuss the melting points of glazes, nor of fused silicates in general. When the temperature of a glaze is gradually raised it becomes softer and softer. The phenomenon of "spitting" shows that the glaze is soft enough, at the temperature of the enamel kiln, to permit the motion of bubbles of gas, just as the bending of a glass rod reared for a couple of months against a wall

shows that glass at ordinary temperatures is soft enough to bend under its own weight. The glaze, however, is not sufficiently mobile in the enamel kiln to re-form a smooth surface in a reasonable time, and thus hide the effects produced by the bursting of the bubbles; although sometimes the edges of the spits (see *a*, Fig. 1) do round off and so produce small "pinholes."

5.—*Gas Bubbles in Glazes from the Glost Oven.*

Glazes usually contain some bubbles of gas, but the transverse section (×45) of an earthenware glaze shown in Fig. 2 discloses the presence of considerably more bubbles than are found in the regular types of earthenware and porcelain glazes. Indeed, a microscopic examination of numerous glazes, both *in situ* and in section, shows it to be highly improbable that any but a few cases

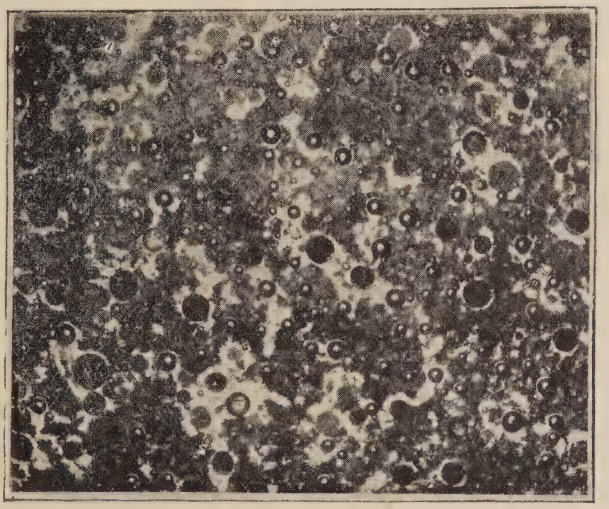


Fig. 2.—Gas bubbles in earthenware glaze.

of spitting can be due to the bursting of bubbles which were imprisoned in the glaze during glost firing. No regular relation has been noticed between the regular types of spitting and the presence of gas bubbles in the glaze before entering the enamel kiln. This, of course, does not refer to the spitting on the "curtain" of a glaze where bubbles of gas are particularly liable to accumulate.

It is sometimes stated that the gas enclosed in the bubbles must be under reduced pressure at the highest temperature of the enamel kiln because a bubble imprisoned in a glaze at, say, atmospheric pressure in the glost oven (1,050°) would be under approximately four-fifths of an atmosphere pressure at the highest temperature of the enamel kiln (800°), so that, when refired in the

enamel kiln, the bubbles would tend to contract, not expand. The mobility of the cooling glaze, however, would in all probability enable the glaze to very nearly adapt itself to the contraction of the bubble of gas, unless the gas were one which condensed to a liquid or solid at the lower temperature.

There can be no doubt that, in the majority of cases, the gas bubbles which cause "spitting" are developed during the firing of the glaze in the enamel kiln. It will be obvious that the gases or vapours which cause "spitting" must have either bubbled through the glaze from the body, or have been actually developed in the glaze itself. We naturally inquire: What are these gases? How do the gases get into glaze or body?

If sulphuric acid condenses on the glaze during the firing in the glost oven, the glaze may be broken up and part of the work which was done in the frit kiln undone, with the result that bubbles are produced in the glaze which may produce spitting as indicated above.

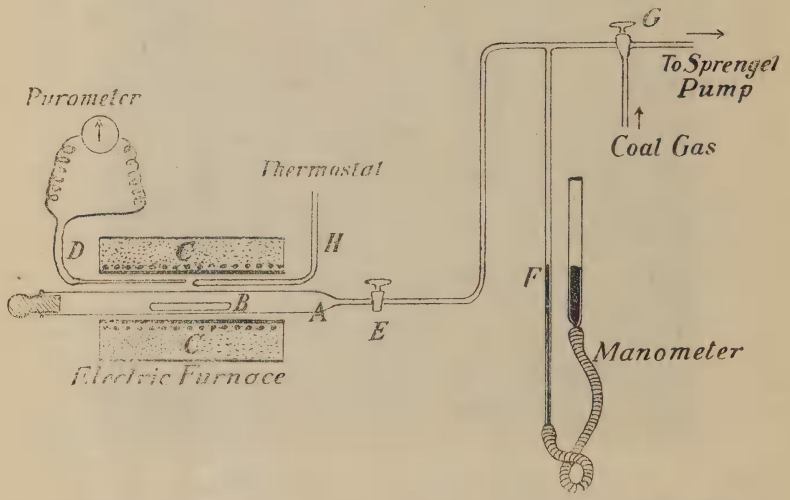


Fig. 3.—Diagrammatic sketch of apparatus for measuring the gases absorbed by hot glazes.

6.—*Measurement of the Absorption of Gases by Heated Glazes.*

It is practically hopeless to attempt to collect sufficient gas from the "unburst" bubbles to permit of even a qualitative test. As a preliminary working hypothesis, therefore, we assumed that the unknown gas or gases work their way into the ware (body or glaze) during the earlier stages of the firing of the enamel kiln. These gases are principally steam and hydrocarbon vapours derived from the distillation and imperfect combustion of the oils and size used in decorating the ware. We first tried if a glaze could absorb hydrocarbon gases in the following manner:

A hard Jena glass tube and a porcelain boat were heated to 500° and cooled three times, under reduced pressure, with a Sprengel mercury pump in operation. The arrangement of the apparatus is shown diagrammatically in Fig. 3, where *A*, is a hard Jena glass stoppered tube; *B*, a porcelain boat; *C*, a nickel wire tube furnace; *D*, a thermocouple; *E*, a two-way stopcock; *F*, a manometer; *G*, a three-way stopcock; *H*, an electric thermostat for maintaining a constant temperature. The illustration (Fig. 4), is from a photograph of the apparatus at work in the laboratory. The apparatus is in the foreground of the photograph. The tube from *E* to G was wrapped round with cotton wool.

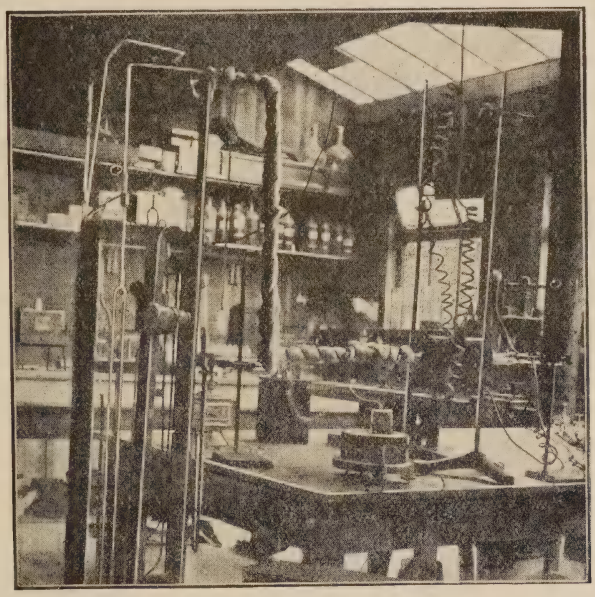


Fig. 4.—Photograph of the apparatus for measuring the gases absorbed by hot glazes.

The apparatus was filled with coal gas and alternately heated to 450°, and cooled as before in an atmosphere of coal gas. It was then exhausted at 15°, and heated two hours to 450°, and again exhausted. The volume of gas was measured in terms of the weight of mercury displaced from a stoppered receiver. The apparatus was again filled with coal gas, and a piece of frit, which had been alternately heated and cooled *in vacuo*, was placed in the porcelain boat. The apparatus was then exhausted. The frit was then alternately heated to 450° and cooled rapidly three times in an atmosphere of coal gas. The apparatus was then exhausted, and again heated to 450° with the mercury pump in

operation. The volume of gas collected was measured as before. The results are :—

Volume of frit	10·92 c.c.
Weight of frit	33·52 grms.

	1st Exp.	2nd. Exp.
Gases removed from tube, and boat ..	7·9 ..	8·7 c.c. at N.P.T.
Gases removed from tube, boat, and frit	13·6 ..	13·4 c.c. at N.P.T.
Gases removed from the frit	5·7 ..	4·7 c.c. at N.P.T.

The gas collected in the receiver burnt with a blue flame. Heres then, is clear evidence of the adsorption of relatively large volume, of hydrocarbon gases by the surfused silicates.*

E. W. Washburn (*Univ. Ill. Bull.*, No. 118, 1920) and co-workers found that all varieties of glass dissolved gases and thus gas is liable to effervesce violently from the liquid glass if the pressure is reduced.

7.—*Related Observations on Volcanic Lavas, Rocks and Minerals.*

This conclusion is confirmed by the observations of O. Silvestri (*Gaz. Chim. Ital.*, **7**, 1, 1877) and A. Brun (*Arch. Sci. Phys. Nat.* (4), 19, 439, 589, 1905), who obtained hydrocarbon gases from the volcanic Etna and Lipari lavas.

It has been known for a long time that many rocks when heated to redness give off large quantities of gases. J. Priestley mentioned the fact in a letter to Josiah Wedgwood in 1781 (H. C. Bolton, *The Scientific Correspondent of Joseph Priestley*, New York, 1892). Later investigations have shown that the gases may be derived from :

(1) Inclusions of carbon dioxide, water, etc., in minute microscopic cavities in crystalline rocks (R. Bunsen, *Ann. Chim. Phys.* (3), **38**, 269, 1853 ; W. N. Hartley, *Journ. Chem. Soc.*, **29**, 137, 1876 ; **30**, 237, 1876 ; G. W. Hawes, *Amer. Journ. Science* (3), **21**, 203, 1881 ; A. W. Wright, *ib.*, (3), **21**, 209, 1881).

(2) Gases occluded in the rocks (A. W. Wright, *Amer. Journ. Science* (3), **12**, 171, 1876 ; H. Erdmann, *Ber.*, **29**, 1,710, 1896 ; W. A. Tilden, *Proc. Roy. Soc.*, **59**, 223, 1896 ; **60**, 453, 1897 ; W. Ramsay and M. W. Travers, *ib.*, **60**, 442, 1897 ; E. S. Kitchen and W. G. Winterson, *Journ. Chem. Soc.*, **89**, 1,568, 1906).

(3) Gases developed by the interaction of the solid constituents of the rocks, *e.g.*, the ferrous salts, the carbon dioxide, and the water of the original silicate (M. W. Travers, *Proc. Roy. Soc.*, **64**, 130, 1899 ; A. Gautier, *Compt. Rend.*, **131**, 647, 1900 ; **132**, 58, 189, 1901 ; **136**, 16, 1903 ; **142**, 1382, 1465, 1906); **143**, 7, 1906 ; *Ann. Chim. Phys.* (7), **22**, 97, 1901 ; *Bull. Soc. Chim.* (3), **35**, 929, 934, 1906 ; A. Brun., *Arch. Sci. Phys. Nat.* (4) **19**, 439, 589, 1905 ; K. Hüttner, *Zeit. anorg. Chem.* **43**, 8, 1906 ; and in

*An attempt is being made to find if there is any relation between the composition of the glaze and the solubility of the gas by A. J. Campbell and J. W. Mellor.

pottery we meet with a reaction between the constituents of bone china which leads to the evolution of phosphorous fumes (B. Moore, Trans., **5, 37, 1905**; J. W. Mellor, *ib.*, **5, 75, 1905**).

8.—*The Nature of the Enamel Kiln Gases.*

Considerable quantities of hydrocarbon vapours must be generated in the earlier stages of the firing of muffles containing groundlaid ware, ware decorated with oils, and lithographed ware (size). Indeed, so much gas and vapour is sometimes evolved that these products burn at the ventilating hole with a blue flickering flame. This probably means that something like 25 per cent. of combustible hydrocarbon gases are present in the atmosphere of the kiln.* We have, therefore, the conditions necessary for the absorption of hydrocarbon gases by the glazes in the enamel kiln when these gases are not cleared away from the kiln in the earlier stages of the firing. Indeed, the ware in the cooler parts of the enamel kiln in the earlier stages of the firing is sometimes covered with a thin film of black or brown tarry and carbonaceous matters condensed from the products of the destructive distillation of the oils and size. This occurs particularly on the ware in the track of the vapours passing to the ventilating hole.

We have also measured the proportion by volume of hydrocarbon gases present in the atmosphere of two kilns. The one a Cartlidge kiln, 1 hour, 1½ hours, and 2 hours after closing the doors; and the other a Climax kiln, every ¼ hour. Both kilns were firing lithographed ware. The former was free from "spit-out," and the latter had a small percentage.

Cartlidge Kiln.

Gases in Muffle	1 hr.	1½ hrs.	2 hrs.
Oxygen	2·5	4·6	6·8
Carbon dioxide	14·2	12·6	10·2
Carbon monoxide	2·1	1·0	1·2
Methane	0·7	0·8	0·3
Hydrocarbons soluble in Nordhausen acid ..	3·6	3·0	2·7

The hydrocarbons are not here present in excessive quantities, but this is no doubt a consequence of the closing of the doors as late as possible.

*Prof. H. B. Dixon informs us that: "When coal-gas is mixed with air, so long as the coal-gas is under approximately 6 per cent. of the mixture, the gas will neither burn at a jet nor will it be explosive. Over 6% of coal-gas may give explodibility to the mixture, and the violence of the explosion increases until the coal-gas forms some 12% of the mixture. On addition of more coal-gas the explosion gradually becomes less violent, and with about 25% of coal-gas and 75% of air the mixture may usually be burnt at a jet. In a Bunsen burner there is roughly 30% coal-gas and 70% air."

Climax Kiln

Gases in Tunnel	B			A		
	1	2	3	1	2	3
Oxygen	1·0	0·5	1·4	3·7	2·3	2·8
Carbon dioxide	15·2	15·6	15·7	13·7	14·2	14·9
Carbon monoxide..	3·3	4·7	2·1	1·7	2·1	1·5
Methane	1·4	1·0	1·6	0·4	0·2	0·3
Hydrocarbons soluble in Nordhausen acid	8·4	7·6	7·9	1·3	1·9	1·1

In the Cartlidge kiln the gases were drawn through a pipe about 3-ft. inside from the doors. In the Climax the gases were drawn from porcelain pipes through the roof of the muffle just clear of the baskets, and in the positions marked *A* and *B*, Fig. 5. The mode of collecting the gases is described in a previous paper by one of us (J. W. Mellor, Trans., **6**, 58, 1907).

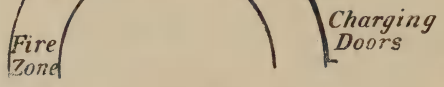


Fig. 5.

We make no suggestion as to how the gases are absorbed by the glaze or body. They may be dissolved, or occluded much as palladium absorbs hydrogen; and silver, oxygen. But, whatever be the mode of absorption, it need not cause a very marked blackening by reduction of the lead. The frit which had been charged with hydrocarbons was slightly more yellow than the original frit.

9.—*Combustion of the Absorbed Gases in the Interior of the Glaze.*

It has been shown that hot glasses are somewhat pervious to oxygen gases (M. Berthelot, *Compt. Rend.*, **140**, 1159, 1256, 1905), and it is suggested that if a glaze be charged with hydrocarbon or combustible gases, and heated in an oxidizing atmosphere, the gases may burn below the surface of the glaze, that is, in the glaze itself. The products of combustion are steam and carbon dioxide, and their formation must be attended with the development of heat. This heat will soften the glaze locally and thus facilitate the "spitting" of the glaze.

This type of spitting has been particularly noticed in the manufacture of glazes in which the colour is developed by firing the glazes, first in a reducing atmosphere, and then in an oxidising atmosphere. The appearance of the "spits" shows that a violent

evolution of gas takes place suddenly. It has also been noticed that "spitting" is more common in kilns charged with groundlaid ware, in which a copious supply of oils has been used in the decoration

10.—*The Absorption of Solid Carbon by the Glaze.*

In view of the fact that in the earlier stages of the firing of an enamel kiln much of the ware may be covered with a thin film of carbonaceous matter; and that a residue of carbon also remains on the ware for a considerable time after the volatile hydrocarbons have been driven off from the oils and size, it is important to remember that in some particular cases a certain quantity of solid carbon may actually diffuse into, or be dissolved by the glaze. The diffusion of solid carbon into porcelain crucibles and cups has been established by the observations of J. Violle (*Compt. Rend.*, **94**, 28, 1882) and S. Marsden (*Proc. Roy. Soc. Edin.*, **10**, 712, 1880).

The film of carbon is quickly burnt off from the surface in an oxidizing atmosphere, but the combustion of that carbon which may have actually diffused into the "solid" glaze or body is a slower operation. If combustion be rapid, "spitting" will naturally be produced as indicated above.

11.—*"Spitting" during the Cooling of the Glaze.*

Under certain conditions, when the kiln is hard-fired, a glaze might take up an abnormal amount of gas and reject it in the form of "spits" on cooling. H. S. C. Deville and L. Troost (*Compt. Rend.*, **57**, 965, 1863; J. B. Hannay, (*Chem. News*, **44**, 3, 1881) noticed long ago the absorption of gases by fused silicates at high temperatures, and the subsequent evolution of the gases on cooling. Evidence of this phenomenon is frequently observed during the cooling of slags run from blast furnaces smelting ores in a reducing atmosphere. For instance, I. L. Bell (*Journ. I. and S. Inst.*, **20**, ii., 532, 1881) describing the cooling of slags run from the Clarence Works, says:—

> "It affords evidence of being impregnated with gas, which, as the slag containing it cools, escapes from miniature volcanoes on its surface, or bursts into small jets of flame from any chance steam which finds its way through the superficial crust."

Not only may hydrocarbon gases be absorbed by fused silicates glass, etc., but other gases—steam, for instance—may be absorbed at high temperatures and escape at low ones. We have also noticed, under certain conditions, "spits" produced during the cooling of the glaze in the neighbourhood of 600°.

There is an interesting experiment with old glass which has been in contact with water for some time. When quickly heated, in addition to devitrification, quite marked spitting may be developed.

The glaze which has absorbed hydrocarbon is often particularly bright, and when fired in the kiln it often becomes eggshelly accompanied by slight spits. This can be produced at will.

12.—*Devitrification accompanied by "Spitting."*

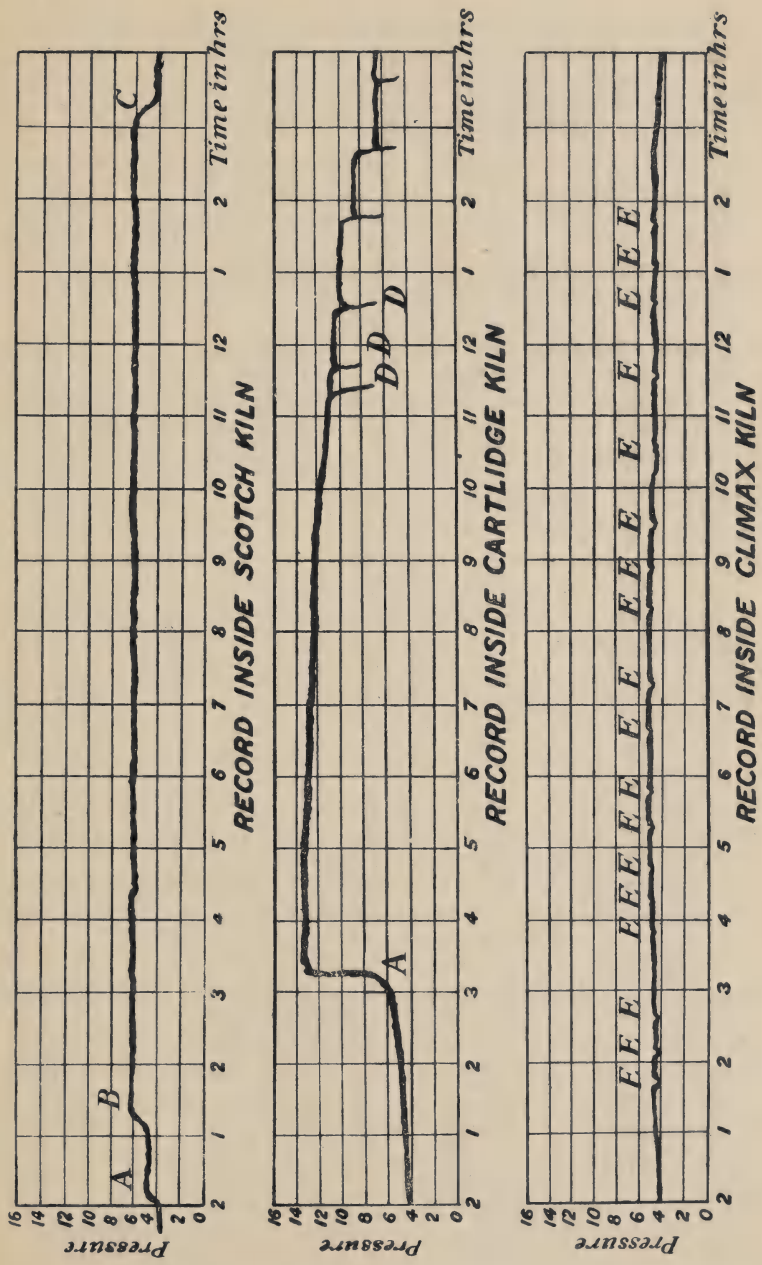
The preceding type of "spitting" is frequently accompanied by symptoms of devitrification. This shows that the solvent power of the vitrified glaze for gases is probably greater than the solvent power of the same glaze in a devitrified condition, or else the disturbance which attends devitrification prevents the supersaturation of the glaze by the dissolved gases.

It follows at once that siliceous glazes or glazes on highly siliceous bodies, calcareous glazes, and, indeed, all those types of glaze which have a tendency to devitrification in the enamel kiln, will be prone to this defect. The obvious remedy in such cases is to augment, if possible, the proportion of the well-known "anti-devitrifying agent"—alumina. This type of spitting is found on the more siliceous vitreous bodies, and we are informed that Messrs. H. W. Edwards, W. Edwards, and S. T. Wilson noticed something similar in their work on "China and Earthenware Glazes" (Trans., **4**, 24, 1904). The glaze gets its extra silica by dissolution from the body in the glost oven.

13.—*The Ventilation of Enamel Kilns.*

In dealing with those types of "spitting" which depend upon the absorption of hydrocarbon gases, or of carbonaceous matters in other forms, it is highly important to maintain the atmosphere of the enamel kiln as free as possible from these vapours during the earlier stages of the firing when the size and oils are being burnt off. This is usually attained in a more or less imperfect manner by keeping the doors of the kiln open as long as possible. But in many cases the ventilation of the kiln is so imperfect that the hydrocarbons accumulate in certain parts of the kiln, and "spitting", if it does occur, is found in those places where we should expect it to be produced, namely, in the worst ventilated parts. Thus, the atmosphere in the interior of hollowware may remain comparatively dead for a considerable length of time, and "spitting" may accordingly be found inside such pieces when the exterior exposed parts are comparatively free from the defect.

In order to get some idea of the pressure which prevails in the interior of an enamel kiln, we fitted a Wright Draught Recorder to three different kilns—a Scotch kiln, a Cartlidge kiln, and a Climax kiln (*A*, Fig. 5). Reduced copies of the records are shown in Figs. 6 (Scotch kiln), 7 (Cartlidge kiln) and 8 (Climax kiln). The instrument multiplies the actual draught or the pressure of air in the kiln 20 times, and expresses the result in twentieths of an inch of water. In the diagrams the records are slightly reduced. In the first experiment with the Scotch kiln, the fires were lighted at 8-30 a.m., the muffle doors closed at 11-5 a.m. The influence of this on the kiln atmosphere is shown by the rise in the pressure at *A* ; at *B*, the fires were raked and "baited" ; *C* corresponds with the opening of the doors ; *D* with the partial


RECORD INSIDE SCOTCH KILN
RECORD INSIDE CARTLIDGE KILN
RECORD INSIDE CLIMAX KILN
Time in hrs
Pressure
A
B
C
D
E

Figs 6, 7, and 8.

opening of the doors; and the depressions *E* correspond with the opening of the doors for the insertion or removal of the baskets. A pressure of "4" on the scale corresponds with zero draught, or atmospheric pressure. The records show that there was practically no pressure in the Climax tunnel.

Draught meters, unfortunately, cannot measure the efficiency of the ventilation of muffle kilns since a *slow* current of gas through a large opening could be more effective than a *rapid* current through a narrow aperture; and of two streams of gas with equal sectional area and equal velocities, the hotter stream will carry away less gas. We have therefore substituted "pressure" in the ordinates of the diagram for the customary "draught."

The conditions under which the absorption occurs, and those which accompany the combustion or evolution of gases from the glaze, are too changeable to permit uniform results being obtained. The draught in some kilns is comparatively great, in others there is practically no draught at all. The ventilation of some kilns is so badly arranged that the atmosphere in the lower part of the kiln is comparatively still, while in the upper part the draught is very brisk.

14.—*The Development of Gases in the Body.*

If the organic matter in the body has been imperfectly oxidised in the biscuit oven, it is obvious that the entry of air into the body in any subsequent firing will cause the combustion of part of the organic matter. The products of combustion heated by the reaction, will work their way under pressure through the glaze, and in many cases produce "spitting." Hence we find this type of "spitting" produced on earthenware which has the faint cream, brown, or bluish-black tint characteristic of ware imperfectly oxidized in the biscuit oven. The effect is more pronounced when these gases pass through bubbles already existing in the glaze.

One type of "pinholing" is produced by the partial levelling of a "spit" or small blister which has been produced in turn by the combustion of organic matter in the body.

A kiln charged with, say, groundlaid ware is very dangerous, because the combustion of the carbonaceous matters will be delayed until the ware has attained a comparatively high temperature. The hydrocarbons act as a buffer, preventing the ingress of oxygen required for the combustion of the carbon in the body. The same remarks would apply to the presence of moisture in the kiln. When the hydrocarbons are cleared at a high temperature, the combustion of the carbonaceous matters imprisoned in the body or glaze will proceed with almost an explosive velocity, and "spitting" results. This interpretation is confirmed by the fact that if the atmosphere of the kiln be kept neutral or reducing at the higher temperature, this type of "spitting" is less likely to occur. But this, of course, is not a practical method of dealing with the defect.

One important remedial measure is to ensure complete oxidation of the organic matter in the biscuit oven in the neighbourhood of 900° before vitrification sets in.

Given a body free from carbon, a vitreous body is less likely to "spit" than a porous body. Given carbon in the body, a vitreous body is more likely to "spit" than a porous body, because the burning out of the carbon in the vitreous body is delayed until the ware has attained a relatively high temperature, when the combustion of the carbon is very vigorous.

Organic matter may also find its way into the body in several ways—imperfect oxidation in the biscuit oven of carbonaceous matters in the bone and clays; reducing gases in glost or biscuit oven, etc. The tarry matters which sometimes condense as a film on the cooler parts of the ware in the enamel kiln during the earlier stages of the firing may find their way into the body through imperfections or discontinuities in the glazed surface. Again, in washing off the "resist" on ware in "acid decoration" carbonaceous matters may work their way into the body, as well as glaze, in a similar manner. It is also interesting to remember that carbon and hydrocarbon gases readily decompose in contact with red-hot porous earthenware bodies with the separation of carbon. The latter is deposited in the pores of the body.

It is well-known that biscuit absorbs moisture which it retains very tenaciously; every analysis of a biscuit body which has been dried to constant weight at 110°, retains up to about one per cent. of moisture which is completely driven off only at a red heat. The adsorption of moisture has been discussed elsewhere by one of us.

In case of a body, however, it is quite possible that definite hydrates are formed which are not usually all decomposed until after the glaze has softened. It is further well-known that the absorption power varies with different bodies. Some have a high capacity for absorption, *e.g.*, the bone china body may form phosphate hydrates.

There has been some misunderstanding about the burning of carbon from the biscuit. The speed of combustion of carbon mainly derived from ball clay in the body increases to a maximum as the temperature rises until the body begins to close up by vitrification changes. The speed of combustion then slows down because vitrification makes it more and more difficult for the air to get at the carbon. Any factor which retards access of air to the biscuit between say 500° and 800° is interfering with the elimination of carbon from the biscuit. Steam for example, may act as a screen for keeping the air away from the carbon. The steam may be derived in part from the evolution of combined water from the clays just over 500°. Good ventilation is the only remedy. A longer period of firing during the period of oxidation favours to combustion of the carbon. It is no good blindly ordering the fireman to take

longer with his ovens. That does no good in this connection, unless the period of oxidation be extended.

There is a caution. Letting more air through the oven may shorten the flame and raise the temperature locally. This may lead to an early vitrification of the body in that quarter of the oven, and this does not favour the speedy elimination of the carbon, rather the reverse. Hence, the paradox, increasing the flow of air through the oven may produce effects characteristic of bad ventilation.

15—*The "Spitting" of Green China.*

There is also a similar type of "spitting" associated with green china, and green china which has become brown in the enamel kiln. The green ware is particularly liable to turn brown in patches in the enamel kiln. The brown patches are frequently, not invariably, accompanied by the "spitting" of the glaze (Fig. 9). The cause of the discolouration has been discussed by one of us (Bernard Moore, TRANS., **5**, 37, 1905). The green discoloration is closely related with reduction. Bone china fired under reducing conditions is particularly liable to the "greening." Hence it is fair to assume that carbonaceous matters are frequently associated with the green coloration. The carbonaceous matter would naturally facilitate the formation of green ferrous phosphate, which, in the presence of air, oxidizes to brown ferric phosphate. The "browning" of the green colour in the enamel kiln thus indicates that oxidation of the ferrous phosphate has taken place. Any carbonaceous matters present at the same time will simultaneously be oxidized. Hence this type of "spitting" is closely related with the preceding types. The "spitting" of the pinkish-brown earthenware and of "greened" bone china are thus related to the "blistering" and "bloating" of black cored bricks. Fig. 9 is an attempt to show in natural colours the appearance of a "greened" and "browned" bone china plate which has "spit" in the brown parts. The spits have been blackened for the photographer by rubbing in lampblack. The black band is the place where a slice was cut from the plate for microscopic examination (J. W. Mellor, TRANS., **5**, 41, 1905).

16.—*"Spitting" produced by Steam and Moisture.*

Another type of "spitting" is an effect of moisture. It is remarkable how tenaciously porous earthenware will retain traces of moisture. The biscuit may imbibe moisture through the unglazed parts, *e.g.*, the foot of a plate, or through any imperfections in the glaze. Such ware, and in particular old ware, if fired in the enamel kiln, is particularly liable to "spit." The moisture apparently cannot get away quickly enough by the path it entered the biscuit and it therefore forces another path through the more or less viscid glaze. It is by no means uncommon, for instance, to find a more

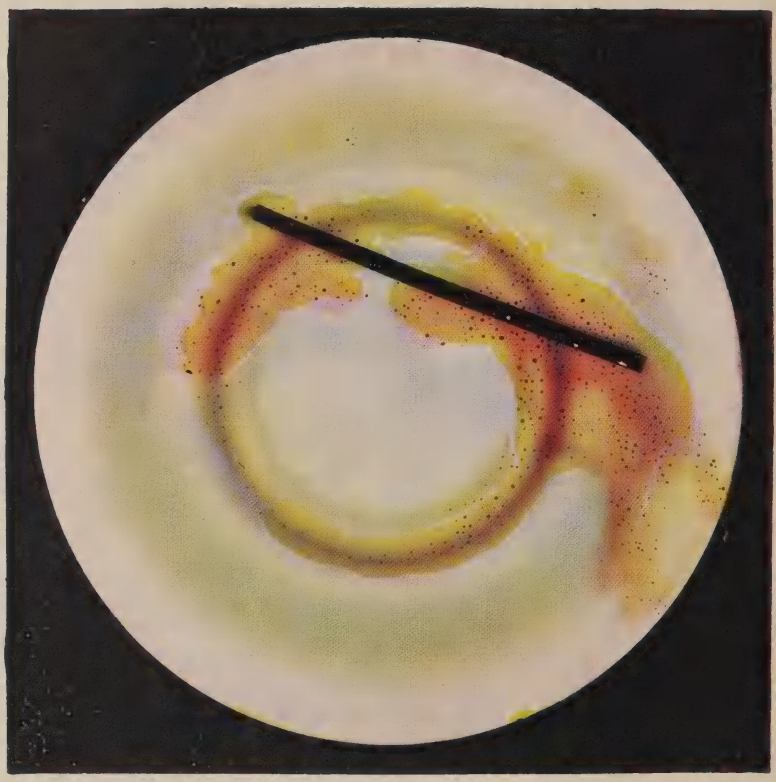


Fig. 9. Diseased Bone China Plate.

Photograph of common white bone china plate which was "greened" in the glost oven, and which developed the "brown stain" when fired in the enamel kiln. The plate was held in front of a bright Nernst lamp, and the spits were blackened by rubbing in lamp black for photography. The black band is the place where a slice was cut from the plate for microscopic examination. The "liquid gold" decoration was removed by dilute aqua regia before photography.

or less perfect ring of "spitting" on the upper side of an old plate above the unglazed foot. It is also remarkable how a line of crazing may be followed by a "spitting" glaze. This species of "spitting" is comparatively easy to imitate experimentally.

It is interesting to note also that green china appears particularly liable to absorb moisture and oxygen from the air. The moisture, of course, may give rise to "spitting" in the enamel kiln, and the absorption of oxygen is evidenced by the "browning" which sometimes develops when the ware has been exposed to the air for some time without heating in the kiln.

Moisture may also appear to act as a reducing agent by cutting off the supply of oxygen and preventing the combustion of the carbonaceous matters in the early stages of the firing. Thus some cases of "spitting" produced by moisture can, after all, be referred to the presence of unburnt hydrocarbons in the ware in the early stages of the firing. These hydrocarbons are protected by the steam from oxidation until the kiln is cleared at a comparatively high temperature. The sudden oxidation of the hydrocarbons at the high temperature is then attended by "spitting."

Many writers on volcanoes have commented upon the enormous volume of aqueous vapour which accompanies the evolution of lava from volcanoes (J. Phillips, *Vesuvius*, Oxford, 200, 303, 1869; G. P. Scrope, *Volcanoes*, London, 20, 45, 1862). Like pottery glazes, volcanic lavas are fused silicates. As the lava cools it gives off immense volumes of aqueous vapours which were confined in the substance of the lava while the lava was being "fired" in the bowels of the earth. When the lava reaches the surface the pent-up steam may be emitted with explosive violence. The phenomena which attend the cooling of volcanic lava illustrate "spit-out" on a grand scale.

It has been remarked that if spitting in the enamel kiln can be caused by the abrupt oxidation of carbon in the body, why does not the spitting show in the glost oven? There is very marked evidence of glost-oven spitting. We have seen samples which could be mistaken for enamel-kiln spitting. We usually call glost-oven spitting by a different name; as long as we do that, it is, of course, impossible to find spitting in the glost oven. Calling the same phenomenon two different names does not make the phenomenon different. It must be remembered that the glaze in the glost oven is very soft, and small spits would quickly heal. The scars of old spits imperfectly healed are not uncommon. The pressure of the gases in the interior of the cooling oven is also rapidly becoming less, reducing the tendency to spitting.

17.—*The Swinton Effect.*

If the glass of a vacuum tube used with hydrogen, argon, helium, etc., gases be fused in the flame it becomes clouded, and, under the microscope is seen to be permeated to some depth from

the inside surface with a multitude of minute spherical bubbles. Sometimes the glass of the melted tube appears to boil, and the bubbles can be seen and heard bursting (A. A. C. Swinton, *Proc. Roy. Soc.*, A. **79,** 134, 1907; F. Soddy and T. D. Mackenzie, *ib.*, A. **80,** 92, 1908). The phenomenon has been called the "Swinton Effect," and there is little room for doubt that it is a particular example of the general phenomena studied in this paper. Physicists have not yet decided to what the phenomenon is due. There appear to be four interpretations;

(1) The bubbles are due to chemical action between the glass and the heated aluminium disintegrated from the electrodes (Pohl).

(2) The gas passes into the glass by ordinary diffusion (J. J. Thomson).

(3) The gas is evolved from the glass by chemical decomposition due to heat (F. Soddy and T. D. Mackenzie).

(4) The gas is driven mechanically into the glass by the cathode rays. When the glass is heated the gas penetrates further and forms bubbles on cooling, much in the same way that air bubbles are formed in ice (A. A. C. Swinton).

18.—*Summary.*

"Spitting" is therefore a highly complex phenomenon, and we have been able to trace the trouble to a number of antecedents, some of which may be referred to the body, others to the glaze. Thus:—

I.—"Spitting" a Glaze Effect.

(1) The sulphates dissolved by the glaze (possibly also by the body).

- (*a*) The diminution in the solubility of the sulphates by an increase in the acidity of the glaze. *E.g.*,
  - (i.) By dissolution of silica.
  - (ii.) By volatilization of "lead."
  - (iii.) "Sucking up" of "lead" by body.
- (*b*) The reduction of stable sulphates to unstable sulphites.

(2) The bursting of gas bubbles existing in the glaze.

(3) The combustion of hydrocarbons in solution in the glaze.

(4) The combustion of carbon in solution in the glaze.

(5) The diminution in the solubility of the gases which attends the devitrification of the glaze.

II.—"Spitting" a Body Effect.

(6) The combustion of carbonaceous matter in the body.

- (*a*) The gases absorbed in the ovens or kiln.
- (*b*) The organic matter in the body. *E.g.*,
  - (i.) "Brown" earthenware.
  - (ii.) "Green" china.

(7) The rapid evolution of moisture absorbed by the body.

In our opinion at least 80 per cent. of the "spitting" which occurs in the manufacture of pottery is due to the presence of moisture or organic matter in the *body*, and this possibly explains why the cause of "spitting" has hitherto proved so difficult to diagnose. Attention has been focussed on the glaze, whereas the glaze appears to be but of secondary importance.

Remedial.

Having located a number of causes, the remedies naturally follow. For example, (1) avoid any cause which tends to produce bubbles in the glaze ; (2) avoid any cause which favours adsorption of moisture by the biscuit or glaze. (3) Have enamel kilns well ventilated so that oils are not distilled from the hot ware and condensed on cooler ware, but are rather carried out of the kiln. If the kiln atmosphere be charged with oil vapours, up to the red heat, and the atmosphere suddenly changes from reduction to oxidation, we have a favourable condition for the explosive combustion of carbon in the body, and this favours spit out. (4) Avoid abrupt rises of temperature, because this favours an explosive evolution of steam, etc. In the case of old ware, the moisture may have taken months to get into the biscuit, and you are attempting to drive it out in a few hours. It may be impracticable without spitting.

DISCUSSION.

Major B. J. Moore:—I had an example from the oven this morning of what I consider to be a spit occurring in the glost oven. I have seen a good deal of this lately. It is due, apparently, to an abnormal amount of either moisture or dirt of some kind that has managed to get into the biscuit. At the last meeting we had on this subject there seemed to be some doubt—at all events on the part of Mr. Miles—as to whether one could get spitting from the glost oven ; or rather, he was puzzled as to why one did not. There is no doubt about it that, under certain conditions, one does encounter spitting from the glost oven, and I think that the piece I have brought here to-night shows signs of spitting, with a tendency for the spits to heal over. Possibly this bears some relation to the question of the absorption of gases or steam by the glaze. It is our experience that ware of this kind seems more liable to spitting and faults of the same family when, at a later stage, it is passed through the enamel kiln. If I might be allowed to go a little further, and express an opinion in regard to kiln spits, it seems to me that the question of the ventilation of enanel kilns is one which offers considerable difficulty. I have frequently heard people say: "Oh, I ventilate my kilns all right. I leave the top of the clammings, or even the top and the bottom of the clammings, open

until the kiln is arriving at a red heat." From this they assume that the kiln is sufficiently ventilated. If, however, one goes to the trouble of following up the passage of heat or of gases, moving in a confined atmosphere, one finds that there is a marked tendency for these to follow a certain course in the kiln rather than to pass through the kiln in general. It is not sufficient to test the amount of air that is passing out through the top of the kiln, for the mere fact that air is passing through the kiln is not sufficient reason to assume that the kiln is well ventilated.

A good way to ensure that an enamel kiln is properly ventilated is to insert two pipes about 1" bore in the bottom and run these right to the back, leaving an opening in the top of the clammings so that whatever air passes into the kiln is first forced to go to the back and then find its way out at the top of the front. I might further state that by leading in air in the manner described, the air is heated up somewhat before it is permitted to come into contact with the wares, and in this way any cooling down of the ware by a sudden inrush of cold air is obviated.

MR. MILES:—I assume Mr. Moore Jr., is referring to a muffle kiln without a damper hole at the back. Some kilns, of course, are constructed not only with a top hole over the iron doors but also a damper hole at the back of the kiln. In the latter case I should imagine that the ventilation would be fairly complete..

MR. MOORE, JR.—It was that very type of kiln to which I was alluding. It is that type in which you have a damper at the back which is most common in the Potteries. My opinion is that if you have air sucked in at the front of the kiln, passing through the damper hole at the back you are almost bound to get a short circuit of air in the kiln. Whilst it may be true that some parts of the kiln are perfectly ventilated there will be other parts which will not be properly ventilated. Air comes in at one place at the front and goes right across to the top of the kiln at the back. I cannot conceive that that is likely to lead to adequate ventilation. If, however, you can succeed in getting the air to take a course across the bottom of the kiln to the back, and then turn up and go back across the top to the front, I should imagine that that is far more calculated to lead to effective ventilation.

MR. F. S. WORTHINGTON:—Mr. Dunbar Bishop wishes me to express his regret at not being able to be present to-night, particularly as he knows how expensive are the losses which manufacturers sustain through spit-out faults. He desires me to ask Mr. Moore or Dr. Mellor whether, in their opinion, newly-ground glaze is more likely to cause spit-out than old, matured glaze. I myself would also like to ask Mr. Miles how he would treat heavily stencilled groundlaid ware. In view of the fact that he stated in his paper two months ago (p. 208.) that moisture was

the cause of all, or nearly all, spit-out, I have been wondering how he would deal with groundlaid and stencilled ware, which you are bound to put into the washing-off tub in order to remove the stencils.

As for the ventilation of the kiln, I fully believe what Major Moore has just said—that you are likely to get far better ventilation by bringing the air to the back of the kiln in pipes and returning it from the back to the front. Our kilns have a damper at the back, but we ventilate by means of the bottom slide door of the iron doors at the front. In that way we manage to get a fairly good ventilation; but we do not get the incoming air hot. We are always having the cold air coming in at the front and out at the back damper. Major Moore's suggestion seems far better, since it leads to the heating up of the in-coming air before it gets into contact with the goods.

Mr. Bernard Moore has mentioned a very important point in his paper with regard to the oxidation of the carbon during the biscuit firing. In our experience this has proved to be one of the finest ways of eliminating spit-out ware in the enamel kiln. We take a rather long time to fire our biscuit ovens until we reach 750 degrees. In this way we have not only minimised the risk of spit-out ware in the enamel kiln, but we have also got rid of the specky dishes that we used to encounter at one time in our biscuit ovens.

Mr. Miles:—Mr. Worthington means, I take it, should I anticipate a tremendous amount of spit-out if the stencilled ware were allowed to remain in the water for some time in order to soak off the stencils? In the ordinary way yes, but there is a way by which this spit-out can be minimised considerably.

Mr. Worthington:—You said, Mr. Miles, that the printed and lithographed ware at your works spit-out through washing off the transfers rather than sponging them off. Now groundlaid and stencilled ware has to be *soaked* in water, often for a long time, in order to remove the stencils. Under these circumstances, how would you get the stencils off without running the risk of spit-out?

Mr. Miles:—In the first place I did not mention any particular works. As to washing off, we do not do it. I suppose the stencils could be sponged off. If the body is porous and you allow it to remain in water indefinitely, you are bound to get spit-out. At least, that is my experience. But it can be minimised.

Mr. Worthington:—I hardly think Mr. Miles knows anything about groundlaid and stencilled ware, or he would not contend that the stencils can be sponged off.

Mr. Miles:—Certainly they can. What kind of stencils is Mr. Worthington referring to? Is he referring to a stencil mixed in oils or a stencil mixed in treacle?

MR. WORTHING:—I am speaking about the ordinary stencils used on groundlaid ware.

MR. MILES:—There are different types of stencils. Apparently Mr. Worthington knows only one. If a stencil is mixed in oil it can be sponged off with turpentine. If it is a treacle stencil it can be sponged off with water.

MR. WORTHINGTON:—I should be inclined to pity any manufacturer who sponged the stencils off his groundlaid ware with turpentine.

MR. MILES:—That is another point. I only said it *could* be done. I do not know to what stencilling you refer, nor whether the mediums in your oils set your colours hard or not. All these and many other points count.

MR. WORTHINGTON:—Precisely, but you would sponge the colour off as well.

MR. C. D. GRIMWADE:—Do the authors of the paper know of any substance which can be added to the body mixing that will promote oxidation of the clays from within? Just as we add cobalt to counteract the iron discoloration in clays, so we seem to require something to counteract the carbon contents in the body during firing.

MR. MOORE:—I am afraid I do not know of anything. There are certainly some substances that could be added to a body that would probably produce spit-out. I believe there is a sample of a very bad spit-out that was apparently produced by introducing lime into a body, the conditions of firing being favourable. Lime, of course, does not combine with the body, but moisture is absorbed by the lime and is retained by it until quite a high temperature is reached. The result, in the instance I refer to, was a very bad spit-out.

In reply to Mr. Worthington's question about the old and the new glazes, I do not think that there is anything in this which bears directly upon our present subject. I suppose I am like many other old potters in the respect that I have rather a liking for a glaze that has been kept for some time, for the main reason that it dips better; it is smoother on the ware, and is more likely than a new glaze to produce a piece of ware that is free from bubbles. Beyond that I should hardly think that old or new glazes would have much to do with the fault of spit-out. It may be that if you have a new glaze, which does nor dip well, and is bubbly, this is more likely to promote spitting than an old glaze which dips more easily. But my mind is open on that particular point as yet.

There are some very interesting samples of spit-out which can be seen on the table and which we should be glad to explain. Here

is a china plate showing blisters which have been produced in the glost oven. This plate was probably fired up to 1,200 degs. C. It was an old plate. Somehow it absorbed moisture; hydrates were formed in the body with age, and when the piece was dipped—it was probably seven or eight years old before it was glazed—huge blisters developed in the body. Although there may be manufacturers who have never come across this fault, it is, nevertheless, extremely common. It seems to me a very remarkable thing that a body which has been fired to 1,200 degrees should blister in this extraordinary way at the lower heat of an enamel kiln at a later stage. It shows, however, that something goes on in the body. Now a modified form of that blister may break through the glaze and cause an ordinary spit-out such as one encounters from the enamel kiln. Possibly most of you have come across odd pieces of a very vitrified body where the body itself has actually spit-out and blown to pieces, this being due to the effect of the moisture that was retained in the body. The moisture was unable to get out at the ordinary atmospheric temperature, but when the heat was raised sufficiently to permit it to escape, it did so—with explosive violence.

Here is another very interesting example of a carbon spit. It is a bowl in which turpentine has been kept for some time. The turpentine was cleaned out, and the cup was fired in the enamel kiln. Wherever the turpentine had managed to penetrate into the cup, such as through a puncture in the glaze, made by a stilt, there is a black patch, and on that black patch there is pronounced spit-out. In the centre of the black patch is a white spot. This is where the air has entered and oxidised the carbon. But of course the damage is done.

Mr. Miles:—With reference to the carbon spitting, supposing that you had a piece of ordinary earthenware and smothered it pretty well with coal dust, charred cocoanut shell, gum or resin, would you expect that to spit-out through the enamel kiln?

Mr. Moore:—Manufacturers may thank the fates that every piece of pottery that has carbon retained in it does not spit-out, for none of them would be in business long if that happened. But what I do say is, that if you have carbon in the body you are *more likely* to get spit-out, for that reason. It is not the only reason, but one of them. You may get 5 per cent. of your spit-out ware from that cause. It may be more. I am not prepared to say how much it is, but I do claim that if there is carbon in the body and the ware is fired in the enamel kiln in such a way that it burns out, you are much more liable to get spit-out than otherwise. I am not prepared to say more than that.

Mr. Miles:—I will pass a saucer up to Mr. Moore showing quite a lot of carbon, and apparently the white patch where it has burned out, as on the bowl to which he has referred. There is no spitting on this saucer. My opinion about the bowl is that the

fault has been due to a reduction of the organic matter, and the evolution of gases in that particular section has caused the spitting.

MR. MOORE:—The saucer that Mr. Miles has sent up is a very interesting one. He has apparently taken a piece of biscuit ware; this has blackened in the glost oven but has not spit-out in the kiln. Now I have never stated, nor am I prepared to maintain, that every piece that contains moisture spits out. If that were so we should have 95 per cent. of our productions spit-out. We are prepared to admit that moisture is a cause of spit-out. As a matter of fact, one of the very things that we have recommended for the prevention of spitting is: fire slowly.—The moisture has gone in slowly, and if it comes out slowly it is not so likely to cause spitting. This is what we wanted to infer when we recommended good ventilation of the kilns. I have no hesitation in saying that if you have a saucer such as Mr. Miles has submitted, it would be less likely to spit out in a kiln with a reducing atmosphere than in a kiln with an oxidising atmosphere. If the kiln is kept reducing the carbon cannot burn. In the bowl that we have shown the spit has only occurred where there is carbon; the other part of the bowl has not spit at all. Surely that would seem to indicate that in this particular instance the carbon is the prime cause of the spitting.

MR. MILES:—The saucer that I sent up was not blackened in the biscuit as Mr. Moore states. It was impregnated with soft soap. My opinion is that the fats have carbonised and given off hydrocarbon gases leaving the carbon free in the body. Yet it has not spit-out. I do not think that carbon, under normal conditions, will cause spitting. I think that it is one of those experiences which is only infrequently met with in practical potting.

MR. FRED CARNALL:—I would like to ask the authors of the paper whether they are of the opinion that, if we blunged our ball and china slip up rather longer and passed it through a finer lawn, this would help to eradicate spitting? Also whether slightly overground glaze is more liable to cause spit-out than glaze ground for the normal period, or glaze underground?

MR. MOORE:—Both of the last two questions are rather difficult to answer. I may say that I have had a good deal of experience with one particular body which is extraordinarily *finely ground*—a body that is probably ground five or six times as long as an ordinary earthenware, resulting in a kind of semi-vitreous ware. Given carbon in that particular body, it is very much more liable to spit-out, because of the fact that the carbon in the body is unable to burn out readily. I am citing this as my own experience.

With regard to the second question as to whether under-ground glaze will tend to produce spitting, in the first place I hardly like the form of the question. *Under*-ground glaze I take to mean

glaze that is not *properly* ground, and, of course, to get the best results the glaze must be *properly* ground. But if you ask me whether *coarse* glaze is more likely to cause spitting than very finely-ground glaze, I should be disposed to reply that very finely-ground glaze is more likely to spit than coarsely-ground glaze. I know definitely that this is so with regard to certain glazes which have come within my own knowledge and experience, but I am not disposed to dogmatise, and to say that this will be so for *every* glaze. As we all know, one glaze does not behave quite like another. If, however, you take a glaze that is entirely fritted, and you grind it excessively fine, you are likely to run a danger of blistering, and to get the glaze full of bubbles. Why? Well, of course, you get the blistering because the glaze vitrifies and skins over very much earlier than it would do if the glaze were coarse. You get the blistering in the glaze in the early stages of the firing, and, as was mentioned in the paper, this is one of the causes of spit-out. You may have seen examples of the blistering of tile glazes, where, during the earlier stages of the firing, the tile has sunk and the glaze stands up as much as half an inch from the tile. My belief is that a very finely-ground glaze is much more likely to do that than a coarse glaze, simply because it skins over more quickly, and the air and gases are more likely to be imprisoned. If the glaze, were coarser, the air that might be enclosed has a better chance of escaping, and blistering is, therefore, obviated. I should imagine that it would be very difficult to blister a glaze if it were so coarsely ground as to be like sand, for instance. If you could manage to dip ware with such a glaze, you would be hardly likely to be successful in getting it to blister during firing. The very fact that a glaze is extremely fine causes it to vitrify at a lower temperature. Dr. Mellor drew my attention some time ago to a very interesting experiment, in which a glaze was so finely ground that by simply warming it in front of a fire it vitrified. I am not perpetrating a joke upon you; it is a fact. I believe that it is quite possible to elutriate a glaze so finely that it will skin over and vitrify in an ordinary bread oven. Dr. Mellor will, I am sure, agree with me in this.

Dr. J. W. Mellor:—Mr. Arthur Heath made some experiments on this subject. He elutriated a glaze so finely that when the glaze was applied to some ware and placed in front of, but not in, the muffle the glaze skinned over. It seems incredible, but the fact remains.

Mr. J. Plant:—Mr. Heath and I were talking together a few moments ago about these experiments to which Mr. Moore and Dr. Mellor have referred. We took an ordinary majolica fritt and elutriated it. The rougher portions of the fritt fired up only in the glost oven, whereas the very finest portions fired up quite alright in the enamel kiln; the different grades in between, we fired up through

muffle kilns. We afterwards tested several fritts, of different compositions, and discovered the same broad characteristics. The rougher portions in every case fired up only at high temperatures, whereas the finer portions fired up fairly easily in the enamel kiln. We ground one for about eight hours, whereas another portion of the same glaze we ground for as long as 160 hours. The result was in every case: the rougher the glaze, the higher the temperature required to mature it; the finer the glaze the lower the temperature necessary.

DR. MELLOR:—There is just one point about the burning of carbon in the body which has not been raised in the discussion this evening, and that is, that there is no change in the volume of the gases during the combustion of carbon in a pottery body. The volume is just the same when the gases come out as before. One has to remember that every particle of carbon in burning under the conditions that we specified, gives off a tremendous amount of heat, and it is the local heating which expands the gases and produces a pressure which ultimately causes spitting. It is not due to any new gas, new volume or anything of that kind; it is simply a straightforward expansion due to heat. The example which Mr. Miles has produced is, I think, simply parallel with own sample, but ours is a very much more accentuated case. It has not spit where the carbon is; the carbon does not make the ware spit. Where there is no combustion of the carbon there is no spitting. That is all it amounts to. There is nothing really remarkable about the sample saucer which Mr. Miles has produced. To my mind it is simply a parallel case to ours, but not so far developed.

XVIII.—A Note on the Slag used in Tile-making at Sarreguémines, Alsace.

By W. Hugill and W. J. Rees, B.Sc. (Tech.), F.I.C.
(Department of Refractories, Sheffield University).

THIS slag was in use, admixed with clay, for the production of vitrified floor tiles.

Microscopically the slag consists of a black, glassy matrix through which nearly colourless crystals are dispersed. The crystals have a resinous lustre.

Microscopic Examination. By ordinary light a few of the crystals are seen to have peg-like inclusions and nearly all are penetrated by cracks. The index of refraction of the crystals is moderately high. Cruciform twins occur (see Fig. 1).

Fig. 1.

In polarised light the crystals are very slightly pleochroic.

Between crossed nicols the birefringence is low and the extinction straight. Many of the crystals show zoning, the outer portion being optically positive and the central part negative; or *vice versa*. Fig. 2 is from a photomicrograph taken with crossed nicols. As shown in Fig. 3, dendritic growths are present in the slag; they were observed to pass directly into crystals. The indications are that the crystals are melilite.

Fig. 2

Fig. 3.

The slag is completely decomposed by hot concentrated hydrochloric acid. Its chemical composition is:—

				Oxygen equivalent.
SiO_2	..	36·00%	..	19·20
Al_2O_3	..	18·65%	..	8·76
FeO	..	2·52%	..	0·56
CaO	..	34·36%	..	9·82
MnO	..	1·60%	..	0·36
MgO	..	2·83%	..	1·13
K_2O	..	1·22%	..	0·10
Na_2O	..	0·56%	..	0·14
CaS	..	1·31%	..	
P_2O_5	..	0·85%	..	
		99·90%	$\frac{\text{Acid oxygen}}{\text{Basic oxygen}}$	= 0·92.

A blast-furnace slag of similar composition is referred to by Baron Jüptner von Jonstorff.[1] The analysis and oxygen ratio of this slag are given for comparison :—

			Oxygen equivalent
SiO_2	37·33%		19·89
Al_2O_3	17·39%		8·17
FeO	2·91%		0·65
CaO	36·86%		10·53
MnO	1·05%		0·24
MgO	2·67%		1·07
K_2O	—		—
Na_2O	—		—
CaS	0·79%		
P_2O_5	0·44%		
	99·44		$\frac{\text{Acid oxygen}}{\text{Basic oxygen}} = 0{\cdot}96.$

Turner[2] gives a slag of somewhat similar chemical composition.

Vogt,[3] by a comparative study of a large number of slags, has shown that the formation of minerals in the molten magma is dependent on the chemical composition of the average mass ; and that with a proportion of from 100 to 55% of calcium silicate to 45% of magnesium iron silicate, gehlenite is formed, provided that the silica ratio does not exceed 0·8. With a silica ratio of 0·8 to 1·2 melilite is formed. The analytical evidence therefore confirms the interpretation of the microscopical examination that the crystals are melilite.

It is probable that British blast-furnace slags of similar chemical composition are available in large quantities.

[1] *Journal of the Iron and Steel Institute*, **61**, 304. 1902.
[2] *Metallurgy of Iron*, 5th Ed. (London, 1918,) p. 227.
[3] *Jern-kontorets Annaler*, Vol. XL., p. 232.

XIX.—Chemical Porcelain.

By Dr. G. N. White.

SINCE the beginning of 1920, research has been carried out at the Royal Porcelain Works at Worcester upon the method of manufacture of Chemical Porcelain. This investigation, which has culminated in the production in England of a hard porcelain, with a resistance to fracture on rapid temperature change equal to the best foreign porcelains, commenced with an exhaustive microscopical examination of the microstructure of existing chemical wares of varying qualities. Concurrently with this examination it was necessary to develop a method of measurement of resistance to fracture on sudden heating or cooling of a given porcelain in order to establish, if possible, some relation between microstructure and quality. The fact that this resistance has so far been found capable of only very approximate measurement (the actual method of measurement being reserved till later) has rendered the determination of this relation a matter of the greatest difficulty, and the opinions arrived at must consequently be considered as somewhat speculative. The microscopic examination gave, in the first place, distinct evidence upon the question of temperature of manufacture, which is a matter of considerable importance, but from the point of view of evolving a deductive hypothesis for further work, the more important result of the examination was that there was, with the greatest probability, some crude relation between the resistance to fracture and the degree of crystallinity of a given porcelain. From this observation it was assumed, purely as a working hypothesis, that there was a factor of crystallization in the fracture of amorphous matter, that is to say, a fracture in super-cooled fluids was, in part, a tentative crystallization, and that the liability to form new surface was reduced by forcing possible crystallization to completion. Super-cooled matter, in general, is in the labile state, the molecules being distributed isotropically and yet they are generally known to be capable of becoming vectorially arranged. In many cases the conditions favourable to the marshalling of the molecules into a crystalline formation are known, whilst in others the degree of super-cooling is apparently so great that this molecular movement has become impossible. In the case of the complex silicates it is generally true to say that the degree of super-cooling is seldom so perfect as to make the conditions of devitrification impracticable, that is to say, there must exist in such material, an appreciable capability of molecular movement towards vectoriality. If a body in which this capability is zero is defined as an ideal body, then in snch a body if all the forces opposing fracture are grouped

together under a single term C (the forces of cohesion), for fracture to occur, a stress F must be applied such that F is greater than C. In all real amorphous bodies it is maintained by this working hypothesis that the stress applied is added to the already existing strain arising from the liability of molecular movement, so that the stress actually required to cause fracture in a real amorphous body need only be such that F^1 is greater than $C^1—V$. That is to say, if C is equal to C^1 then F^1 is less than F. It might be here mentioned that it is not necessary that a body approaching the ideal should have a minimum tendency to fracture, for this is decided by the relative values of C and V. It is to be expected that cohesion in a body should be lowered by crystallization, and if the amorphous matrix is entirely removed by crystallization, the force required for fracture would be small. To obtain resistance to fracture in real amorphous bodies, it is necessary that they be made to approach the ideal by the term V representing the capability of molecular movement or tendency to crystallize being brought to a minimum (without appreciable lowering of the cohesion) by an approximation either to the perfect fluid on the one hand, or to the perfect solid on the other. Homogeneous super-cooled fluids, such as glass or fused silica, show an increase in resistance to fracture as they become more perfectly vitreous. Heterogeneous super-cooled fluids, of which hard porcelain is a type, in general, illustrate the converse case in which resistance to fracture is raised by conversion as far as possible into the crystalline state. It is not sufficient merely that the crystallization shall have commenced—the resistance to fracture being (as judged from microscopical examination) proportional to the ratio of the amount of crystallinity produced to the amount capable of production. It is thus held that by inducing crystallization to the greatest extent, the tendency to further crystallization is reduced to a practical minimum. When we apply this theory to hard porcelain we are dealing with a material of which the composition varies between narrow limits. The body consists in the raw state of clay, silica and base bearing mineral, and on burning becomes, at least in intermediate stages, a heterogeneous mixture of aluminium silicate and an isotropic solution of silica, silicates and alumino-silicates. Commencing at the stage at which this composition prevails, a reaction occurs which may be considered analogous to the following, at least in that it leads to the formation of an alumino-silicate:—

$(Al_2O_3.\ SiO_2)\ SiO_2+K_2O.\ nSiO_2=K_2O\ Al_2O_3\ (n+2)\ SiO_2$

This is intended to represent the solution of dehydrated clay in the matrix of the body. In ornamental porcelain the reaction stops at this stage, but in hard porcelain it proceeds further:—

$K_2O\ Al_2O_3\ n+2\ SiO_2=Al_2O_3\ SiO_2+K_2O\ (n+2)\ SiO_2$ (2)

which represents the decomposition of the alumino-silicates with the formation of sillimanite. This is almost certainly a reversible reaction, so that a rise in the proportion of bases (shown as K_2O)

throws the reaction to the left and inhibits the formation of sillimanite. Apart from this fact it is also highly probable that a high proportion of bases lowers the actual rate of the reaction, so that it not only requires a longer time to attain equilibrium, but yields a smaller proportion of sillimanite when it has done so. In the process of manufacture the reaction never reaches the position of equilibrium even under the most favourable circumstances, with the result that a body high in bases is composed for the greater part of super-cooled material removed considerably from its equilibrium proportions. The conditions in such a body are, therefore, ideal for capability of molecular movement, and there should exist high molecular tension for any external stress to work upon. Such porcelains are found by experiment to be very low in resistance to fracture. To obtain stability the reaction (2) must approach completion; that is to say, the bulk of the alumina must have crystallized out as sillimanite. As the reaction proceeds, however, the bases concentrate in the matrix and tend to stabilize the alumino-silicates. In general, therefore, the formation of sillimanite is the more complete, the lower the proportion of bases, but as a certain proportion of them is essential for this second reaction to occur, there is consequently a theoretical reason why a total crystallinity in hard porcelain is impossible. In practice the problem becomes one of determining the minimum proportion of bases which gives under practicable time-temperature treatment a totally impermeable body. As an example of the above considerations, a comparison between two hard porcelain bodies made at Worcester can be made. In body *A* the composition was such that if the whole of the alumina had crystallized out, the burned body would consist of 70·2% sillimanite. The matrix, however, remaining would then consist of only 71·2% SiO_2, and 28·8% bases. Actually the alumino-silicates have been stabilized to an extent that allows only of a production of sillimanite of the order of 25%. Body *B* was designed to have a composition such that the total crystallization of the alumina should give a body having 45·3% sillimanite, leaving a matrix consisting of 94·5% SiO_2. For hard porcelain this concentration of bases in the matrix is unusually low, with the result that the amount of sillimanite formed under the same temperature-time treatment as body *A* is in the order of 38%, that is, more than in the more aluminous body *A*. Measurements of the thermal stability of these two bodies show that the resistance to fracture varies with the efficiency of the sillimanite formation, which is also the percentage of silica in the matrix. Body *A* gives a value of 210, and body *B* gives a value of 240 and 250, which is believed to be about the limit for chemical hard porcelain.,

The estimation of resistance to fracture on rapid temperature change may now be dealt with. A very large number of experiments have been carried out to arrive at a reliable test which will give a

numerical value for the quality of a chemical porcelain. The number of tests which have been put forward from time to time give a "break or stand" result, which for the present purpose is useless. In this connection it is worthy of note that the most rigorous test that can be applied to any porcelain is to place a large crucible or small basin made of it on a tripod, and to heat it directly over a strong Bunsen burner, of which the flame is so arranged as to bring the inner cone well up against the base. Only exceptional pieces of the best wares will withstand it in spite of the same pieces remaining intact through other tests which appear far more drastic. Several methods of measurement of resistance to fracture which were unsuccessful, and, therefore, need not be detailed, have involved unknown factors which gave rise to unaccountable variations. The principle of all tests was the same, namely, to plunge into water a piece of porcelain equally heated throughout to a known temperature. The difficulties occur in heating the piece to some 300°—360°C with certainty of the temperature being equal at all points, and also in the removal of it from the heating chamber to the cold bath. The heating of a length of porcelain tube by electrical resistance and then forcing through it at a given temperature a rapid stream of water is precluded when comparison between foreign porcelains is required, as certain irregularities are introduced owing to the glaze, which is of necessity present in the case of foreign porcelains. It was considered, on the whole, more satisfactory to immerse the pieces of equal measurements in a bath of molten material (sodium bisulphate was actually employed) kept at a definite temperature and then merely to remove them by heated tongs rapidly into a bath of eosin solution. It was found that with practice and proper precaution against draughts, this method gave consistent results. Any test, however, which tries a porcelain to its breaking point, reveals a variation in a given body of the resistance to fracture, which necessitates a mean value being taken from a large number of pieces. The mean temperature at which at least twelve pieces just fracture on the cold immersion is determined, and the value recorded at that value less 100, since on the immersion the surface of the ware is in actual contact, not with cold, but with boiling water. The temperature of the water, or eosin solution, was found to have no effect upon the "temperature of fracture." Although this method cannot be considered quite satisfactory, it yields results of definite value in placing an index figure on the quality of a chemical porcelain. Bad low-fired wares have a value about 160; Worcester 1921, about 210; Royal Berlin, 225; Japanese 240; and Worcester 1922, 240.

DISCUSSION.

MR. BERNARD MOORE:—We all feel very much indebted to Dr. White for coming before us with this paper, because the subject is

one of great interest to the whole country. We wish him every success in the work in which he is engaged, for we are all anxious to see produced in England a type of chemical porcelain that is better than anything that has ever been produced in the past.

I should have liked to have heard a little more from Dr. White on the influence that a glaze has in withstanding the changes of heat. Anyone who has had any experience in such matters often finds that whilst amazingly good results are obtained where there is an absence of glaze, *i.e.*, where the ware is made without glaze, when the same kind of body is used with a glaze the difficulties are considerably increased. I hope that there will be a good discussion, because the matter is one in which we all ought to display considerable interest.

Mr. A. G. Richardson:—I agree with Mr. Moore that we have all greatly appreciated the paper, and I have much pleasure in moving a most hearty vote of thanks to Dr. White for bringing it before us. Many points of interest have been brought forward. Mr. Moore has mentioned one, namely, the great difference in results which is sometimes experienced when a glaze is added to a theoretically perfect body. We shall all be glad to have an opportunity of going more closely into the paper after it appears in print. Dr. White's investigations into the production of chemical porcelain at Worcester must enlist the interest of British potters in general, and we all hope that his work may have the effect of placing the Worcester productions in the forefront of the chemical porcelain of the world.

Dr. J. W. Mellor:—I have great pleasure in seconding the vote of thanks to Dr. White. We all feel, I am sure, that we should have liked to have read the paper carefully before venturing any definite opinion on the points he has raised, because it is so easy to misunderstand a lecturer without pre-reading a copy of the paper. I am afraid in a number of cases I have misunderstood what Dr. White has said. I wish he had given us a definition of porcelain at the start of the paper. I think that the most important thing that Dr. White has said to-night is that the Worcester porcelain resists abrupt changes of temperature better than the Berlin porcelain.

I agree with Dr. White that it is very difficult to get a satisfactory test for the resistance of porcelain to abrupt changes of temperature. With the exception of the sodium bisulphate test, I have seen performed all the tests he has described. I understand that this test consists in pouring the molten bisulphate from a basin, and then suddenly cooling the basin. Of course, there is a variable factor in the time taken to pour the stuff from the basin and place it on the cooling slab. I trow that these tests are not satisfactory. The real test is the percentage loss per man in a laboratory run by professional chemists. If a fracture occurs in a long analysis, pounds worth of labour and materials may be lost. The most successful chemical porcelain (or glass for that matter) for professional workers is that where the risk of fracture is smallest.

Under those conditions a shilling or two extra for basin or beaker does not come into consideration.

There has been a good deal of work performed on sillimanitic porcelain which Dr. White has not mentioned. There may be good reasons for not mentioning it, but I think investigations date back to the eighties of the last century, and from that time onwards our knowledge has been greatly increasing.

As an illustration of how easily we can misunderstand a lecturer, I may cite Dr. White's introductory remarks about the annealing of glass. I take it that in the annealing kiln or the lehr—as the glass people call it—you are converting the glass from an unstable system into a stable system—that is to say, you are reducing its tendency to crack. If, however, it is allowed to stay in the annealing kiln too long the glass begins to crystalize, so that by annealing you are evidently carrying the glass nearer towards the stage of crystallization. That, I think, hardly fits in with the way I understood Dr. White to explain the toughness and brittleness of the glass. I understood Dr. White to say that the higher the proportion of the crystalline matter to the amorphous matter in a porcelain, the higher its power to resist fracture in consequence of abrupt changes of temperature. I think the subject is very much deeper than would be represented by a statement such as that.

Some time ago I came to the conclusion that *the greater the proportion of crystals in the body, the greater was its tendency to fracture*. Thus, my findings would appear at first sight to be entirely opposed to Dr. White's. The Germans and others have previously expressed the view accepted by Dr. White, that *the greater the proportion of crystals the less the tendency to fracture*. Here are two statements, each based upon observation and which seem to be directly contradictory. I think the explanation is that the crystallization under the conditions described by Dr. White is such that the matrix in the process of cooling has time to adapt itself to the crystals. During the crystallization, I assume that there is a tremendous contraction in the material as a whole, that when the matrix which furnishes the crystals crystallizes there is a big local contraction. Now, if that contraction occurs under conditions where the matrix has not time to adapt itself to the crystals, it seems to me—I cannot imagine anything else—that strains will be set up and, of necessity, there will be a greater tendency to fracture either with percussion or with a change of temperature. On the other hand, if the conditions are such that the newly formed crystals and the matrix can adapt themselves to the changes in volume, then I can understand how the anastomosed crystals might make the body tougher. This being so, the two statements are not really so contradictory as they might at first appear, rather do they compliment one another.

I did not intend to say so much. My object in speaking was to second a hearty vote of thanks to Dr. White for his very interesting

paper. My interest thus got the better of my discretion. I would like to congratulate Dr. White upon his statement that the Worcester porcelain is better than the Berlin, and I hope that this will be fully borne out by subsequent experiments. If it really is so, I think he will be deserving of our greatest congratulations.

DR. WHITE:—I thank you for the way in which you have received my paper.

With regard to the various questions that have been put forward, the first of these, raised by Mr. Moore, had reference to the effect of the glazing of a biscuit body. The only unglazed body that I have had any experience of has been the Worcester body, and I may say that in that case I have not found any very great difference between the glazed material and the biscuit body. I have heard other people say that there has been noticed a marked effect of glazing a body—in other words the resistance of the body to heat changes has fallen upon glazing. It may be that we manufacture our biscuit ware at Worcester in a different way, or it may be that the Worcester body is an exception to the general rule. At any rate, I have carried out a number of tests with both the glazed and the underglazed porcelain, but I can find very little difference between the resistance qualities of the two. If we could find an ideal test—I do not put forward the bisulphate test as an ideal one—which would give us some absolutely reliable indications as to the resistance to abrupt changes of temperature, it is quite possible that we might find variations in the Worcester porcelain between the glazed and the underglazed varieties. With our present implements, however, I have not been able to find any.

I must thank Dr. Mellor for his kind references to the Worcester porcelain, but I hope it is quite clear to you that the good results which have recently been obtained, and which indicate that Worcester porcelain is better than either the Berlin or the Japanese, apply only to some recent trials of mine. Our present, regular Worcester chemical porcelain, when the bisulphate test is applied to it, gives a figure slightly lower than Berlin, although I do not think the figure is one which makes very much difference. Worcester comes out at something like 310, whereas the Berlin is 320.

From Dr. Mellor's references to my statement that ceramics are a hundred years behind the times, I am rather inclined to think that he has misunderstood me. I was criticising the chemistry of the complex silicates in order, if I could, to point out that our present knowledge of the complex silicates is about comparable to, let us say, ether or alcohol in the very early days of organic chemistry. I made no aspersions whatever upon the potting industry of to-day. I know perfectly well that the ceramic industry has made great strides. I am inclined to think that it has progressed to an extent comparable to any other industry that might be mentioned. What I wish to point out is that the difficulties in the

study of the complex silicates are so great that really one cannot compare the chemistry of this particular branch of knowledge with, say, the chemistry of the photographic materials of to-day. You have to go back to the chemistry of alcohol in 1840 to arrive at anything like a true comparison.'

With regard to Dr. Mellor's remark about the crystallinity of saggar material, I do not wish for a moment to offer a criticism of his views on the adaptation of the matrix to the crystals, but we can look at the matter in another way. For instance, it is possible that you can carry on crystallization to such an extent that you depreciate what we may call the cohesion of the body. It is possible that we may be able to crystallise to such an extent that ultimately the body would fall to pieces. If you crystallise your matrix out entirely the body would probably fall to bits, although, in practice, the limit to which you can take the degree of crystallization is probably not more than approximately 90 per cent.

By way of a written communication to avoid any misunderstanding, let it be added that the degree of crystallinity in a body does not of necessity indicate its resistance to fracture, because there is a lowering of cohesion after crystallization has passed a certain point. The thing that is dependant totally on the degree of crystallinity is the hypothetical crystallization factor V which should be zero when the body is totally crystalline. In such a body the stress required for fracture would then have to exceed the undiminished cohesion, but owing to the variation of this quantity with crystallinity the breaking stress in such a body might easily be lower than in one in which the crystallinity was less. The main idea is simply this, that in the fracture of amorphous bodies a devitrication factor exists which arises from the capability of molecular motion towards vectoriality and that this factor is measured by the ratio of the amount of crystallinity produced to the amount capable of production. The best non-fracture body is that which has the maximum cohesion with minimum devitrification factor.

XX.—The Use of Ceramics in Architecture.

REPORTED.

The lecturer, Professor A. Beresford Pite, M.A., F.R.I.B.A., in summarising the points dealt with, in a previous paper emphasised how the permanence of ceramic materials enabled one to trace with little difficulty the architectural developments of the ages, the prevalence of the architectural use of ceramic material in Assyria, Etruria and the Greek lands, its great antiquity and its wide distribution. The permanence of ceramic materials as applied to the architecture of the past entitled them to greater respect and application by the architects of modern times. "Nowadays," said the professor, "we build in steel and in ferro-concrete such structures as demand an ornamental covering—a filling in of the panels or a clothing of the surface walls with some decorative material. We talk about the naked construction of a building, and we turn with a sort of instinctive horror from a naked ferro-concrete structure. To-day, therefore, we have an apportunity for suggesting that the typical ferro-concrete building could, and might, and ought to be clothed with a ceramic garment, which has the advantage of permanence and of bright and clean colouring, combined with economy of outlay. The possibility ought to be faced, because it is obviously more economical to cover a structure that is self-supporting with a surface that is only an inch or so in thickness—the thickness of a tile or plaque—than to cover it with 12 inches or 18 inches of masonry. The economical aspect of the question is, therefore, important." To the architect, who, in a general way, might be said to occupy, if not actually to own, the field of operations, what was the appeal of ceramic faience ? Firstly, it had form, and was capable of being modelled so as to convey almost any degree of relief; secondly, it had colour—and the stimulus to the imagination was considerable when one reflected upon the possibilities of combining modelled form with a real measure of full and varied colour, although the judicious use of the two was another and separate subject ; thirdly, it offered absolute permanence of both material and colour ; and fourthly, it had the saving grace of cleanliness—if it should get spotted it was capable of being cleansed. Such advantages, taken in combination, ought to recommend to the architect the use of faience without any hesitation. There arose, of course, the question of cost. But if it cost more money, was it worth more ? Were the qualities that were obtainable from the employment of ceramics in the field of architecture worth paying for ? If so, how much were they

worth? This, however, was a question which, he thought, lay very largely in the hands of the faience manufacturers.

In considering the use of faience for architectural purposes, it might be well to deal with the question under a number of practical heads. First of all there was the treatment of plain surfaces in faience; secondly, there was the treatment of modelled surfaces such as mouldings; thirdly, there was the use of architectural ornaments; fourthly, there were superficial or surface decorations; and fifthly there were insertions, such as plaques or shields, set in other materials.

Under the first head—that of plain surfaces—he would like to consider any structures or walls built of fireclay, terra-cotta or carrara ware. In the use of faience in this way, structurally, there were practical difficulties in adhering to stonework dimensions and forms. Unfortunately, the designer was habitually designing fireclay buildings as if he were at work upon stone. His courses, joints, corbels, and stonework structures he expected to be translated into faience. Here the architect was fundamentally wrong, if he set the manufacturer the problem of producing faience blocks in the sizes of stonework blocks. There was no need for that at all. To adhere to a stonework method of design when dealing with a material that was not stonework was quite unnecessary. Seeing that the materials were fundamentally different, the method of the design must also be different. The difficulties at once emphasized themselves when one actually came to build; because, whilst there was no difficulty whatever in adjusting a block of stone to its position in the building by cutting, this could not be done with equal celerity in the case of faience. Stonework was a solid material, whereas faience was not. It had to be remembered that blocks of faience had to be hollow, and that the hollows had to be filled in either after the blocks were fixed or when they were about to be fixed. This led to practical difficulties, and he wanted to suggest in this connection the practicability of employing, when using ceramic blocks, ordinary brick sizes, instead of stonework sizes. It seemed to him that if they employed the sizes of standard bricks in the designing of fireclay buildings, with their multiples of $9'' \times 4\frac{1}{2}'' \times 3''$, brick and a half, two or three bricks, and so on, this would greatly facilitate the use of faience as a building material.

The only objection that might be made was, he ventured to suggest, no real objection at all. It might be argued that that if faience were to be used in smaller blocks more joints would be involved. But was that a drawback? Everyone knew the usefulness of a good broad joint in a brick wall. Its chief practical usefulness was that any unevenness in the surface of the bricks could be corrected in every individual course—the bricks could be levelled all the way through. A suggested drawback in the case of terra-cotta blocks was that if these came out of the kiln slightly uneven they required dressing and all sorts of handling before

they could be fitted closely together; but this was a difficulty which could be met if the building were carried through with more and with wider joints. At the present time there was a fashion in joints; the wide joint was very popular. The use of this wide joint might conceivably tend to make faience popular. Then again, if smaller-sized blocks were used, both twisting and filling might be avoided. How far the twisting would be eliminated the manufacturers would know better than he, but if the smaller blocks were used manifestly there would be less twisting during the firing. With regard to the filling, he would only suggest that there were such sizes known to brickmakers as "soaps." A "soap" was half the thickness of a brick, and a thickness of $2\frac{1}{4}''$ was not a thickness that would require filling.

Now was there not a further advantage in suggesting the use of brick sizes when dealing with plain surfaces such as walls? Bricks lent themselves to mass production. He imagined that the real difficulty that presented itself to the mind of the architect in the employment of terra-cotta and faience was the difficulty of producing the material in mass quantities. No-one would care to stock it, and every time it was required it would have to be made specially, involving all manner of difficulties and delay, both to the architect and the builder, and that general topsy-turveydom in organisation that almost inevitably ensued in dealing with a terra-cotta building. It was not uncommon, for instance, to get delivery of the terra-cotta for the cornice before the terra-cotta was delivered for the plinth. If, however, the material could be produced and stocked in bulk for use, and become adaptable owing to its standard sizes, as was the case with bricks, surely this would have the important effect of reducing the present relatively high cost of ceramic building materials. And reduction of cost would imply a larger use of such materials.

If standardisation of sizes could be agreed upon, the main present difficulty of the architect and builder would disappear, viz.: the difficulty of obtaining the material at the beginning of the building operations instead of having to wait patiently for its progressive manufacture. Stocks of standard sizes of materials and standard colours could be accumulated, for they would not deteriorate, and if the materials became popular they would not be a drug on the market. Only a few colours would be required. He did not think any architect ought to employ more than two tones on the same building, merely for the purpose of contrast, such as black and white, or grey-green and cream or red. He did not wish to make any rash promises, but if he knew he could get with facility blocks of Pietra Serena and cream, he thought he could promise the manufacturer a very big market. The architectural difficulties could and would be dealt with. The possibility of facing buildings with such beautiful colour tones as Pietra Serena, alternated with the ivory or cream of Florentine stucco, was suf-

ficiently attractive and possible of success to be seriously attempted. If these materials were obtainable, what new applications were possible in the way of glazed brick work in general simple masses such as the fence and enclosure walls of gardens or factories! And he was predicting, imagining, prophesying a material that was not going to cost anything like so much as the glazed brick work of the present day. He fancied this could and would be achieved.

Turning to the treatment of moulded surfaces and modelled forms, the lecturer said that if a whole wall were glazed, the value of modelled architectural or ornamental forms in an *unglazed* ceramic material, or perhaps stonework, offered a variety in texture which was always interesting. He could not, however, readily recall any outstanding experiment in the way of using variety of texture in a ceramic building. The Natural History Museum at South Kensington was, of course, of wholly unglazed work externally, but his suggestion was that if the surface of the wall were glazed, the modelled surface would gain by contrast if it were unglazed, or if the entire scheme were arranged *vice versa*. Cast work in moulded surfaces should not be unduly repeated, although he did not think there need be any despair about the possibility of producing forms which would bear repetition. Obviously, the great advantage that terra-cotta or faience would hold over stonework was that one mould could be used for the manufacture of many lengths, or great quantities, on mass production lines. He did not see why, for walled surfaces, modelling should not be employed. If the mason, in order to get contrasts of texture in the use of stonework, imitated what was called rustication, why should not the texture of a modelled material be varied in a similar way for a similar purpose, by giving each block a central spot, or bevelled edges, or matted surface. Any or all of these should be entirely legitimate in terra-cotta or faience. He could imagine a matted surface produced in a semi-glazed ware that would be extremely pleasant to the eye. The central ornament of the block could be produced in the mould. He would, however, advise his manufacturing friends not to go in for those terrible things such as decorated skewbacks and ornamental keys, of which there were some notorious 40-year old examples in the region of South London.

For the modelled parts of a wall a plinth was always a necessity, and in a plinth the weakest element was the vertical brickwork joint, which caught the weather. This seemed to offer opportunities, which should not be ignored, for the use of faience plinths. A water-proof plinth moulding—a well-designed base—was quite as important as a well-designed cornice, and in the production of such a plinth an impervious, permanent material such as faience, fireclay or terra-cotta was eminently desirable. If, in addition, the manufacturer of ceramic materials could offer the architect

glazed faience copings with water joints, how much better these would be than the perishable coping materials that were at the present time very commonly employed. For strings he would suggest only simple curved forms such as could be used in mutual combinations, and the cornice tables and brackets should be on a limited scale. Such ornaments as annoyed one by repetition should be rigorously avoided. In casting ornaments for relief, such forms as eggs and leaves should not be employed. A simple geometrical ornament, such as a nail head or a billet, or a Greek geometrical key, was preferable. He would like to enter a caveat against reinforced concrete lintels; they were not true, and often entailed twists and joints. For the architraves and pilasters masonry forms should likewise be avoided. He could confidently say that he had never yet seen a circular faience column that looked really well. Entasis in faience was always absurd.

In considering architectural ornaments he would like the manufacturers of faience to realise to a greater extent the characteristics of plastic modelling, which would offer to the designer an amount of scope for original surface treatment, both in the way of expression and technique. In designing ornaments the designer should endeavour to realise the essential difference between mechanical repeats and free ornament. The one was bond: the other free. Both had their merits; the one had the advantage of multiplied and continuous service; the other the merit of entire freedom. If the nobler form were used, then it should be used as if it were *really* noble. He would suggest that in using glazed work for ornament, sharply marked projections should be avoided, for the reason that they caught the light too brightly. The material should be treated as though it had the intractability of granite, for when it was fired, it was actually quite as intractable. Seeing that stonework precedents should be avoided, this seemed to imply the necessity of a new school of plastic design, differing from all the usual methods. Surely there was sufficient material here for fresh thought and study.

Superficial decorations implied either tile insertions or casings, such as were employed in big quantities in Arab and Moorish art, for the entire encasement of buildings such as those which were to be seen, for instance, in Bagdad. He was inclined to suggest that for external decoration quantity was essential. Small friezes or panels of superficial ornament were of no use whatever. The artistic idea must be that of a beautiful clothing or skin: it need not be expressive of construction. It might be very interesting even though it were manifestly non-constructive. There was here offered a great opportunity for richness of effect and variety of flat drawing and of colour. He knew, of course, that there were problems connected with the weathering as well as with the nature of the materials. But this was a problem for the manufacturers. The only problem for the architect was connected with the fixing

of such materials, and he was quite prepared to undertake the risks in that respect, seeing that he had made a notable experiment some 20 years ago, which had not been attended with the slightest sign of failure.

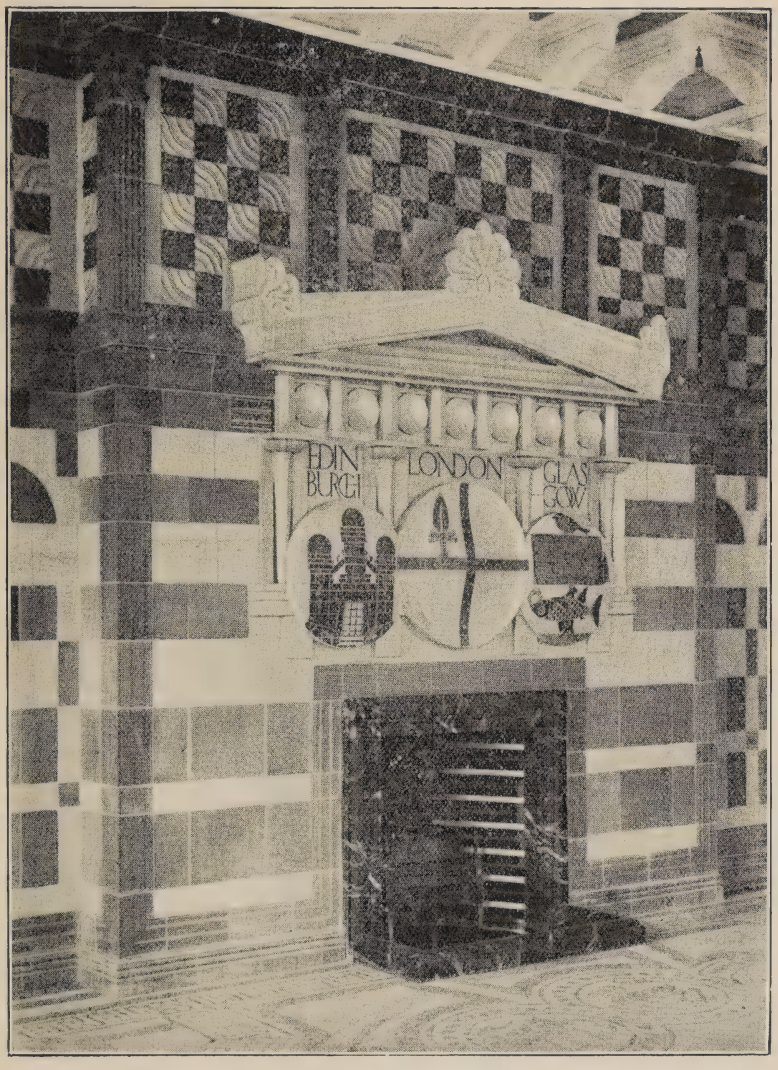
The study of insertions was a smaller field. He was referring now particularly to panels. It was significent that one fine panel would lend power and interest to a whole façade. The extraordinary value of the Della Robbia work was that it presented the interest of sculpture in combination with peculiarly brilliant and perfect colour. This was a great combination which had yet to be developed in the treatment of architectural faience. A great sculptor and a great colourist could concentrate the interest of a design upon a mere frieze or panel. And if the frieze or panel failed, then the whole scheme failed.

Sufficient had probably been said to illustrate that there was abundant scope for the study of the greater application of faience to architecture. Such a study, however, was in the main the interest of the producer, for the public was inert. It was the producer who must create the demand as well as supply it. One could not help reflecting that it was rather amazing that so little had been done by the great sculptors of our country in the direction of combining permanence of body and delightful colourings with their native art of modelling. What handsome war memorials we might have had in faience had there been the men to do it! There was no material more permanent than faience, and surely permanence should be the first quality for memorial purposes. It was regrettable to think that some of our war memorials were already decaying.

Concluding, the lecturer said that he was convinced that a school of study in connection with architectural faience ought to be established, and why not at the Royal College of Art at South Kensington? What was wanted was a living connection between such a school of study and industry—a real liaison between the two. The public, also, ought to be educated, and the only way in which the public could be educated was by illustrations. The experimenting should be done by a school, and it should be brought from the condition of experiment to the condition of demonstration by those who knew the practical difficulties. He could only suggest that the producers of faience should combine—that a society for the furtherance of the improvement of architectural faience should be formed in order to erect examples, as an investment. He was perfectly certain that there would be no difficulty in putting a faience front on a building if it were offered for nothing, and a few hundreds or thousands of pounds would be a very economical advertisement if it resulted in wholesale business later. It was a line of business that might perhaps be more profitable than pots and vases, and he thought there was no reason why such a business should not be created and extended. It might be found a real

economy to endow a professorship at the Royal College of Art with a view to creating this much-needed link between the industrialist and the designer.

Entrance Hall, Insurance Office, Euston Square



Mantel, Entrance Hall, Insurance Office, Euston Square.

Paganis Restaurant, 42, Great Portland Street.

XXI.—The Rope Drive.—Its Design and Maintenance.

By P. Kenyon.

THE essential differences between rope and belt driving are:—(*a*) The rope is carried in a groove so shaped that there is always space below the rope in which there is free air; (*b*) The rope drive generally consists of a number of ropes; eighty ropes are run from one pulley in one instance, whilst the majority of cases comprise from six to thirty endless ropes.

The advantages claimed for rope drive are as follow:—(1) *High efficiency*. Unfortunately, in this country, too little attention is paid to the purely technical side of any question, familiarity and old established custom being sufficient for most people. As any tests, on a practical scale, of the efficiency of a rope drive are practically prohibitive on the score of cost for the manufacturer, we have to turn to the Continent for exact data. The first curves shown in fig. 1 give the influence of loading together with velocity on efficiency.

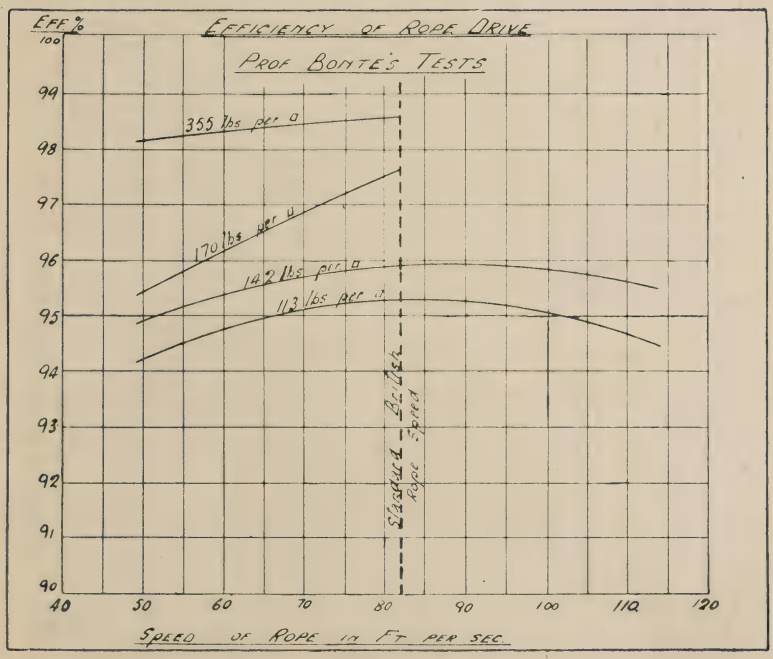


Fig. 1.

It will be noted that at 355 lbs. per square inch the efficiency is over 98% at the slow speed of 50 feet per sec. (3,000 ft. per min.) and over 98·7% at the standard British rope speed approximately 82 ft. per sec., *i.e.*, 4,920 ft. p. m., with every indication that at still higher speeds the efficiency would be greater. At 170 lbs. per square inch the efficiency is 95·4% at 3,000 ft. p. m.; and 97·7% at 5,000 ft. p. m.; at 142 lbs. per square inch the efficiency attains a maximum of nearly 96% at approximately 5,500 ft. p. m.; at 113 lbs. per square inch the efficiency attains a maximum of 95·3% at a speed of approx. 5,000 ft. p. m. The second curves give the influence of loading at fixed velocities. (See fig. 2)

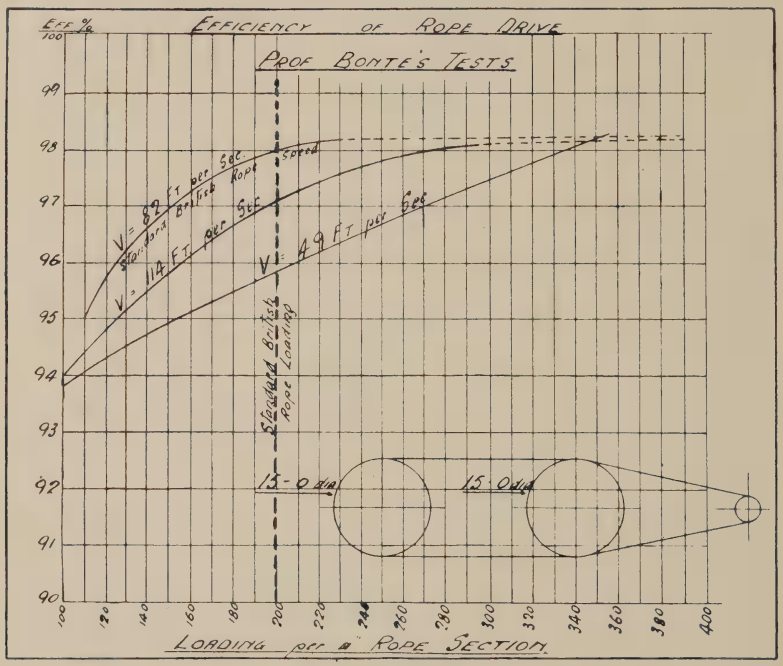


Fig. 2.

It will be noted that:—At 82 ft. p. s. a load of 110 lbs. per sq. inch gives an efficiency of 95%, rapidly increasing to 98·2% with a load of 230 lbs. per sq. inch and thereafter remaining constant. With lesser velocities the loading must be heavier in order to attain the same efficiency, though this is attained ultimately. The standard British loading—200 lbs. per sq. inch—gives an efficiency of 98%. From these tests, the following general principles may be deduced:—Maximum efficiency is obtained with maximum load. Maximum efficiency is obtained at a speed something over 5,000 ft. p. m. The limitations of the apparatus pre-

vented efficiency tests at a higher speed than 5,000 ft. p. m. under the heavier loads. It is reasonable to assume, however, that the crown of the curve, in the first diagram, will move to the right with the heavier loads. It may be stated, therefore, that efficiency of a rope drive, assuming correct design; is between 97 and 99 per cent. In our opinion, the standard British loading—200 lbs. per sq. inch—can be increased to 250 or even 300 lbs. per sq. inch without detriment when other conditions of the drive are suitable.

(2) *Reliability*. On a correctly designed drive, stoppages on account of rope failure are practically unknown.

(3) *Adaptability*. Ropes are eminently suitable for the distribution of power to various lineshafts from one large prime mover, *e.g.*, the modern cotton mill. Awkward conditions, such as are met with in angular and vertical drives, shafts out of true alignment, etc. are easily overcome.

(4) *First cost* and maintenance charges, particularly for large installations, are less than with any other system.

(5) *Positive Driving*. There is absolutely no slip on a properly designed rope drive and the creep, which for most purposes is negligible, can be calculated and allowed for if absolute speed ratios are desired.

(6) *Resilience*. Thanks to the spiral construction of a rope and to the superior elasticity of the cotton fibres, which material is now almost exclusively used for the manufacture of driving ropes, it largely absorbs any shocks in the transmission and damps cyclic variations which may be set up at either end with the result that a smooth steady turning moment is obtained. This is important and accounts for the wide adoption of cotton ropes for driving rolling mills of all descriptions and for their growing popularity in ring frame driving.

(7) *Noiselessness*. The rope drive is practically noiseless.

(8) *Less space and less interference with lighting*. A $1\frac{3}{4}$" dia. rope will transmit as much power as a 5" ordinary double thickness belt at the same velocity. A comparison between rope and belt driven rooms will strikingly demonstrate this point.

(9) *No Electrical Disturbances*. This is due to the complete absence of slip, and consequently diminished waste of energy. If there are electrical phenomena, this is a sure sign of something wrong with the drive.

(10) *High Speeds* can be obtained with combined efficiency and economy. (See graph of effect of speed on efficiency). The best speeds at which ropes should run depend upon the various conditions of each particular installation. Generally the best speeds are :—For main drives 5,000-6,000 ft. p. m. For light and single rope drives 3,000-4,000 ft. p. m. Speeds up to 7,000 ft. p. m. are fairly common and have given none but excellent results, whilst an instance of a rope speed of 8,750 ft. p. m. is on record.

An example taken from a Lancashire Cotton Mill may be

quoted here :—Thirteen ropes $1\frac{5}{8}$″ dia. convey the entire load of card room and five spinning rooms from a driving pulley 28′ dia. making 80 rev. p. m. ; this gives a rope velocity of 7,033 ft.p.m. The card room itself requires three ropes only for 286 H.P., that is, 95 H.P. per rope.

At another mill owned by the same Company, 24 ropes $1\frac{5}{8}$″ dia. transmit the power from a 28-ft. dia. driving pulley running at 50 rev. p.m. or 4,396 f.p.m. ; thus using 84% more rope for a somewhat smaller duty at the lower speed.

The instance of ropes running at 8,750 ft. p.m. is at a Belgian Iron and Steel Works. The driving pulley is 3·18 metres (10′5″) dia. weighing 12 tons and running at a speed of 268 rev. p.m. The driven pulley 1·55 metres (5′2″) dia., weighing 6 tons, at 550 rev. p.m. 12 Ropes $1\frac{3}{8}$″ dia. transmit a load which, on occasions, exceeds 1,500 H.P., or 125 H.P. per rope. Square hemp ropes were formerly used on this drive and on an average these lasted three months and required tightening every week. Patent Interstranded Cotton Ropes were substituted on a guarantee to last 6 months. These have given an average effective life of 18 months and require tightening about once during this period. These instances do not mean that it is always advisable to go to such high speeds, but that they may be used if conditions demand it, provided a shorter rope life in terms of time is allowable.

Rope Pulleys are generally made of cast iron and may be cast solid, or in halves, or smaller segments, afterwards bolted together, according to the size of the pulley and the conditions under which it may have to run. For high speed works, pulleys have been built of steel somewhat in the manner in which a bicycle wheel is made. It is important to ensure a safe pulley when high speeds are under consideration.

The importance of design, good casting, correct turning, boring and balancing, and high polish of grooves cannot be over-emphasized. The manufacture and finish of the pulleys is equal in importance to the selection of the rope. Too often, pulleys are purchased taking price into consideration solely. On examining the grooves of a rope pulley which is and has been in use, these grooves will always be found to have a high polish. The most expensive way to polish a groove is to let the rope do it. Incorrect boring or balancing may cause rope surging, this often being the primary cause of rope failure, if nothing more serious. Bad casting means a decreased factor of safety as a pulley rim, like a chain, is only as strong as its weakest section. Poor design may mean serious casting strains, though the pulley may be heavier than is actually necessary. It thus follows that, when enquiring for pulleys, full details should be given so that if any special features are necessary, the pulley maker may design accordingly. The width of the pulley face may be found by multiplying the pitch of the groove by the number of ropes and adding from $\frac{1}{2}$″ to $1\frac{1}{2}$″—

according to the size of rope—for the extra width of outside flanges.

The most important factor to decide in designing a rope drive is the number and diameter of ropes required. The power that each rope will transmit depends upon :—

(*a*) Rope diameter.
(*b*) Rope speed.
(*c*) Pulley diameters.

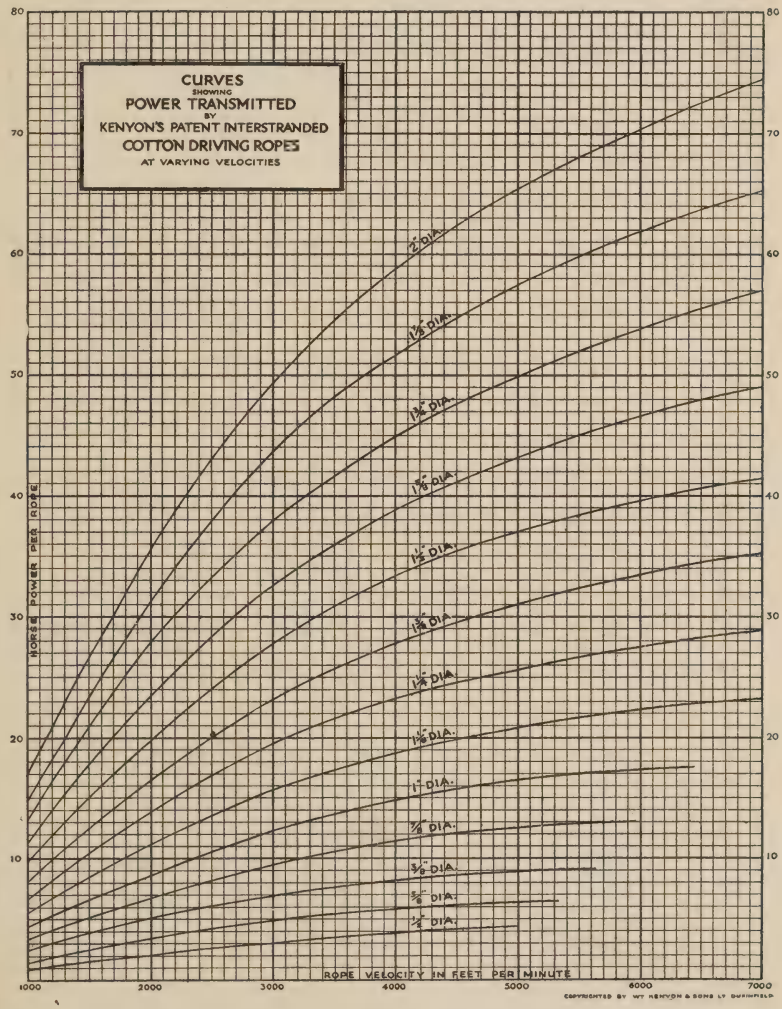


Fig. 3.

It is impossible to give figures which will meet every case. The graph, however, (Fig. 3), shows the variations in the power that will be transmitted by ropes at given speeds over pulleys which are suitable for the size of rope used.

This graph is founded on extensive practical and technical experience and may be relied upon absolutely, provided the pulley diameters are not less than those specified in a graph No. 4.

It will be noted from the above graph, that the powers transmitted by all sizes do not decrease immediately the speed becomes greater than approximately 4,900 ft. p. m. To explain this, some discussion of the effect of centrifugal tension on the rope drive is essential.

Centrifugal Tension. In determining the power a rope should transmit, the old method was to arbitrarily fix a total allowable tension, generally determined by the empirical formula :—

T equals 160 D^2 where D is the diameter of the rope in inches.

The centrifugal tension is then determined for the various speeds by the formula :—

$C.T.$ equals $\frac{v^2 \times w}{g}$, where "v" is velocity of rope in ft. p. s. and "w" is weight in lbs. of 1-ft. of rope.

Then the effective tension equals :—T minus $C.T.$ and the power transmitted equals $\frac{(T \text{ minus } C.T.)\ v \times 60}{33{,}000}$

This gives the well known curve which shows that at 8,300 ft. p. m. approximately no power at all is transmitted. This is obviously wrong from the teachings of practical experience. Furthermore, no account of the "back tension" (initial tension) has been taken, which certainly exists and could lower the curve still more.

As a matter of fact, the power a rope should transmit depends upon :—Total allowable tension, which may be varied according to circumstances ; the point at which the rope will slip in the groove, this depending upon the pulley dia. and the effective tension, the amount of wear on the rope due to bending under strain—this being a practical point of supreme importance, since reliability is perhaps the most important feature of any method of power transmission.

Total Allowable Tension :—There is never any danger of this exceeding the elastic limit of the rope at the speeds at present used, much less breaking it, so that the consideration of advisable duty may be limited to "slip and wear."

In support of this, let us assume a $1\frac{3}{4}$" dia. rope transmitting 57 H.P. at 7,000 ft.p.m. (see graph), the back tension being 100 lbs.

Then the effective tension equals $\frac{57 \times 33{,}000}{7{,}000} = 269$ lbs.

The back tension equals 100 lbs. and the centrifugal tension equals :—

$$\frac{wv^2}{g} = \frac{1 \times \left(\frac{7{,}000}{60}\right)^2}{32} = 425 \text{ lbs.}$$

Therefore, total tension equals 1,194 lbs.

The breaking strain of a "P.I." Cotton Driving Rope is 22,000 lbs. ; that is, the total tension is only ·054 of the breaking strain.

Slip. Without going into the involved calculations necessary to determine the requisite back tension and arc of contact required for various sizes of rope, we may say that the curve of Minimum Advisable Pulley Diameters has been built up from these considerations giving full weight to actual results obtained in practice. When it is remembered that various authorities give the coefficient of friction of a rope in a cast iron pulley in figures varying from ·075 to ·88, the difficulties of a purely theoretical solution become obvious. Leboutre gives ·075, ·088 and ·15; Unwin ·28, and Pearce Bros., Dundee, ·57 to ·88.

Wear. There are two ways in which wear takes place :— External wear—due to contact between rope and pulley. Internal wear—due to bending under strain. External wear varies inversely as the square of the diameter, *i.e.*, a 2″ dia. rope wears proportionately one fourth as much as a 1″ dia. rope under the same conditions. For all except small ropes external wear may be neglected. Internal wear varies directly as the total strain, as the velocity and as the cube of the diameter of the rope when bending round the same radius. In most rope drives *internal wear only* need be considered, assuming a sufficient arc of contact and back tension to prevent slip.

On the above lines also backed by extensive observations of actual installations, the curves of Minimum Pulley Diameters have been evolved. (See Fig. 4). This curve should be used in conjunction with the H.P. curve previously given.

Pulley Diameters. The most important consideration in regard to pulley design is that of fixing the minimum diameter which will give a satisfactory rope life ; once this has been determined it may be exceeded with consequent improved rope life, but to go below the minimum is to ask for a short and unsatisfactory life. The graph shown entirely supersedes the old empirical rule "The pulley diameter must be at least 30 times the rope diameter" which takes no account of velocity or of actual rope diameter except as a simple multiple. In many cases the maximum diameter pulley that can be installed is fixed by local conditions. In these instances it is necessary to vary the rope diameter to meet the conditions. *It is better to overload a small rope than to work a large rope over a small pulley, so long as the slipping point is not reached.*

Grooves. It is now generally admitted that straight-sided grooves are the best, but there is some difference of opinion about

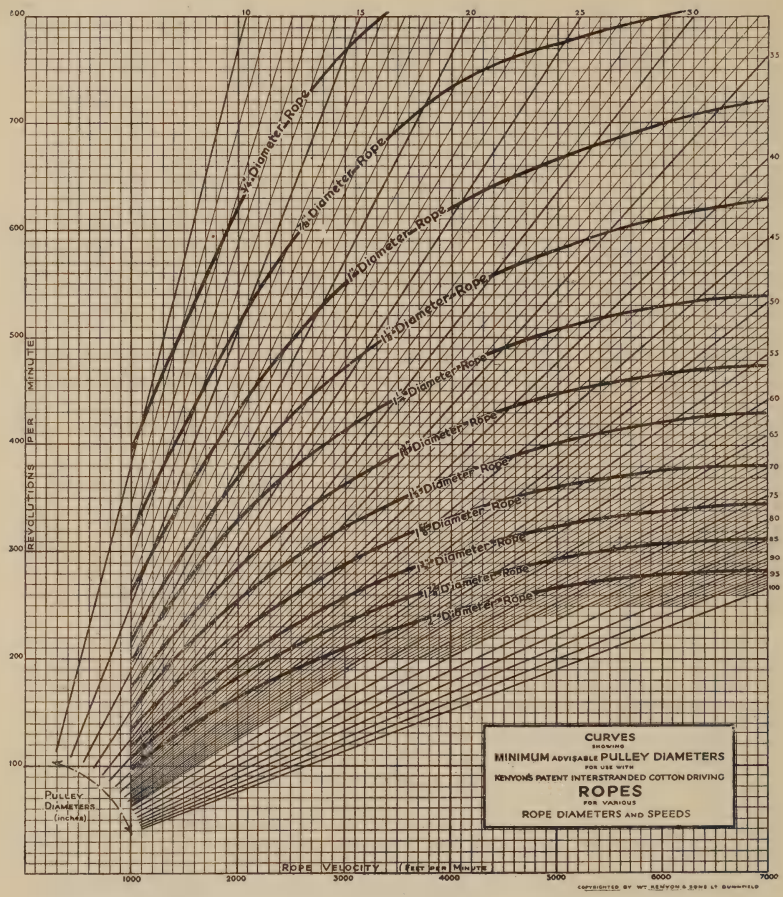


Fig. 4.

the correct groove angle and the necessity or otherwise of flanges.

In my opinion, the best groove angle will be found to vary with the different conditions. Some degree of standardization, however, is very desirable, so that for all ropes 1″ in diameter and upwards, a groove angle of 40° is advised, whilst for either the multiple or continuous system of driving 45° should be the limit for any conditions. For ropes below 1″ in dia. a groove angle of 30° is advisable, and for very small bands a more acute angle still may be used with advantage. The chief objection to the flanged groove is that the flanges are not of the slightest use, whilst at the same time they make the manufacture more difficult and are necessarily more expensive. (See Fig. 5)

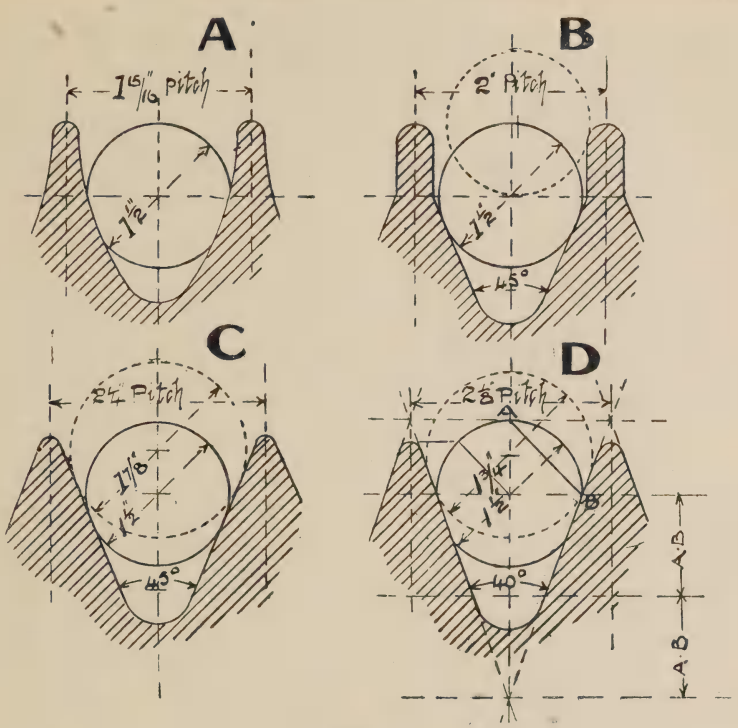


Fig. 5.

Flangeless grooves have the following advantages :—They are easier to turn, finish and polish; they will take a larger range of rope sizes; and do less damage to oscillating ropes.

Dia. of Rope.	*Pitch of Groove.*
$\frac{1}{2}''$	$\frac{3}{4}''$
$\frac{3}{4}''$	$1\frac{1}{16}''$
$1''$	$1\frac{3}{8}''$
$1\frac{1}{4}''$	$1\frac{11}{16}''$
$1\frac{1}{2}''$	$2\frac{1}{16}''$
$1\frac{3}{4}''$	$2\frac{3}{8}''$
$2''$	$2\frac{3}{4}''$

Centre Distances. In many cases the centre distances are dependent upon existing conditions and consequently fixed. Should this not be the case, however, it is almost impossible to lay down any rule except that, unless circumstances dictate otherwise, centres should not be too close. A fair empirical rule is to multiply the sum of the pulley diameters by two. Thus, centre distance equals $2(D_1 \text{ plus } D_2)$.

The minimum centre distance is only limited by the clearance

required between the pulley rims provided that certain allowances are made in the duty required from the ropes. This should be fixed at about 75% of that given by the graph. (See Fig. 3). This ensures that the ropes will run their normal life without requiring tightening by re-splicing, which is impossible under these conditions. The maximum centre distance varies according to whether the tight side is on top or underneath. In the former case the maximum centre distance may be taken as 14 times the mean pulley diameter. For the latter case there is practically no limit provided the sagging rope does not foul any obstacle.

Centre distances of 100 ft. are quite common and instances of centre distances up to 200 ft. are not uncommon. Generally speaking, the centre distance has little or no effect on the life or efficiency of the drive and may be decided solely from constructional considerations.

Guide Pulleys. In certain cases, *e.g.*, angular drives, obstructions, etc., guide pulleys are necessary to deflect or support the ropes. In order to minimise wear and loss of efficiency, guide pulleys are best introduced on the slack side of the rope wherever possible. In many cases, however, it is essential that these be fixed on the tight side or on both. No matter where fixed the same rules as to minimum diameters apply and under no circumstances should these rules be violated. Too small a guide pulley will have exactly the same effect on rope life as too small driving or driven pulley. In addition to this, guide pulleys must have efficient lubrication and in many cases ball or roller bearings are very advisable Furthermore, these pulleys must be accurately cast, turned, balanced and polished just as a working pulley. The groove, however, is of a different form. This should be of the "U" type and on multiple drives should be of exactly the same pitch as the working pulley grooves.

If guide pulleys are inclined, thrust bearings are necessary in certain cases, particularly for heavy work on the tight side of the ropes.

As it is not my province to go into the details of millwrighting, perhaps it will be sufficient to say that bearings, shaftings, etc., must all be up to their work and correctly designed and installed if the best results are desired.

Though it is quite possible, and in fact is often done, to drive from one shaft to another out of parallel without the intervention of guide pulleys, it is much better to have correct alignment throughout if this is at all possible.

Under and Over Driving. It is a popular error that all drives are best arranged under-driven. In most cases it is of no great importance whether the drive is under or over driven. The principal advantage of the under-drive is that the arc of contact on the pulleys is increased by the sag of the ropes. If there is a considerable difference in pulley diameters, or the drive is highly inclined, then

this is of some importance though the loss of arc of contact is easily remedied by allowing extra ropes. For high speed drives, other conditions being suitable, the over driven type will give a longer rope life as it entails less internal wear. In cases where the load or effort is variable in nature and tends to set up surges in the rope, the over driven type is again the best as there is then much less tendency for the rope to jump out of the grooves and less external wear is entailed.

Inclination of Drive. A rope drive will give the best service when the centre line is horizontal. This ideal condition is not always possible and it is in no way essential. For drives up to 45° no allowances are necessary. For inclinations of 45° to 60° up to ten per cent. extra rope is advisable. For inclinations greater than 60° from ten to twenty per cent. extra ropes become necessary. Where the lower pulley is smaller than the upper, or the drive is over-driven, a further allowance is often advisable. There is no difficulty in arranging even vertical drives on the above lines, but extreme cases require care and the full consideration of all factors.

Sag of Driving Ropes. If correctly spliced and fixed at the outset, the maximum sag on the slack side of the rope may be approximated at $7\frac{1}{2}\%$ of the centre distance. The rope race should consequently be arranged to allow for this much clearance. It is not, however, always possible to allow anything like so much space under the ropes, but a minimum of 5% is strongly to be desired as anything less than this would chafe the ropes before they had stretched sufficiently for satisfactory tightening. If space is very limited, the most economical remedy is to put extra ropes on to the drive to ensure that they never stretch sufficiently to allow touching the obstruction.

Angular Drives. A rope drive can be installed wherever there is one shaft to be driven from another, their relative positions and inclinations never prevent ropes being used although each case requires separate consideration. Many bevel and spur gears have been profitably replaced by ropes—notably on rolling mills and wire drawing mills. The number of types of angular drives is large—a few examples of which are shown on the diagrams.

Care of Driving Ropes—Storage. If not required for immediate use, the coils of rope as received from the maker should be placed on baulks of timber in a warm, dry, well ventilated place. Rope should never be stored on a concrete or earth floor, in a damp place or unheated outhouse.

Splicing and Fixing. This work should, wherever possible, be left to the makers of the rope. As this is not always possible—particularly abroad—instructions should be obtained for the guidance of the local splicer, who quite experienced with one class of rope, may make an absolute failure of another. It is impossible here to go into these questions in detail, but we have recently published brochures on the subject which we will forward on request.

Dressing Ropes. No liquid or semi-liquid dressings should be used on cotton driving ropes as the absorption by the rope is detrimental. The safest plan is to obtain rope compound from the makers of the rope and follow their instructions. Too much dressing is worse in effect than too little.

Obstructions. Ropes must never be allowed to foul anything in their flight, otherwise perpetual trouble and a very short rope life will inevitably result. If the obstructions cannot be removed, then guide pulleys are required. Rollers must not be used as these are generally worse than the obstruction itself. If there is not sufficient room for guide pulleys, less damage is done to the ropes by running on a well greased board than by running over a roller.

Acid and other Gases. Ropes should be isolated from these, particularly when they may be mixed with steam or water vapour. If isolation is impossible, the ropes should be kept well coated with composition to the point of excess and the pulley grooves scraped out periodically. In some cases it is advisable to coat the ropes with rubber solution.

Dust, Grit, etc. Dust, especially if at all gritty, is very deleterious to cotton driving ropes and where this abounds the ropes should, if possible, be encased in dust proof sheet-metal cases. If this is not possible, the ropes should be brushed frequently and regularly along the fibres and in one direction only, afterwards applying rope composition sparingly. The latter must never be applied until the ropes have been brushed.

Dampness, Water and Steam. These are always injurious to cotton ropes when present in any quantity and should therefore be excluded if possible. In any case, keep the atmosphere as constant as possible in which case great damage will not result even if there is a large percentage of humidity. Use rope compound to reduce absorption to a minimum.

High Temperatures. Practically no trouble will be experienced with cotton ropes from this cause. A little rope dressing is all that is needed to prevent a tendency to stretch. Should stretching occur, on no account use water to tighten the ropes as this would certainly ruin them.

Machinery Standing Idle. If the drive is to stand for any length of time, the ropes should be blocked, *i.e.*, blocks of wood should be inserted between the ropes and the pulley rim with the aid of the barring engine or tackle. When starting up, the removal of these blocks ensures against hot bearings or similar trouble.

Oscillating Ropes. Oscillation or surging in ropes never comes from any defect in the rope itself. It may be caused by bad design, or from quite unforeseen causes, or from false economy in the first place which is really the same thing as bad design. The usual causes are :—

Large cyclic variation in prime mover together with the slight float which is necessary with any pulley.

Pulleys seriously out of true.
Variations in load.

Flywheel effect and true pulleys are the obvious remedy. Unfortunately, we are often confronted with the actual fact and invariably the rope maker is asked to cure the trouble without any radical alteration in the drive itself. A rope guard is the best practical remedy under the above conditions and, notwithstanding the flimsy construction, is almost always effective. (See Fig. 6.)

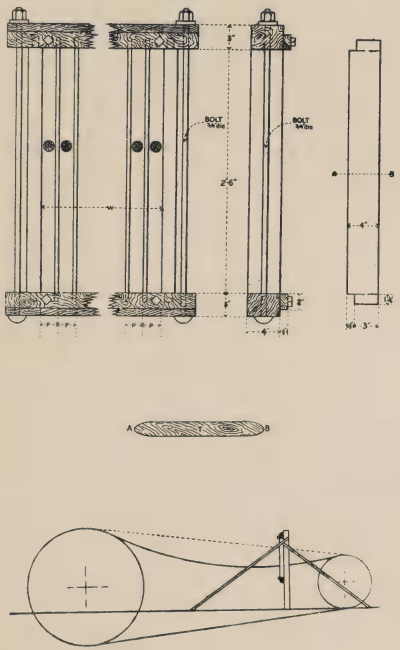


Fig. 6.

In certain cases—two so far in my experience—every factor was such that it became absolutely impossible to prevent the ropes throwing themselves off. The alterations in diameter of the driven pulley was effective in each case. Often rope oscillation can be much minimized by either under or over-loading the ropes—generally the former, or by tightening.

APPENDIX.

The Particular Application of Rope Driving to Potteries.

The most important application of rope driving is seen in the main drives from an engine house to the various first motion line

shafts, of which so many good examples are furnished by the Lancashire Cotton Mills. In all industries, however, the rope is used to distribute the power to the ultimate machines from and through a large number of countershafts. A modern factory, well planned out, offers no difficulty to this system, but the conditions in a typical pottery are by no means so admirable from the point of view of power distribution. The scattered disposition of the works, due partly to gradual development and partly to the necessities of the industry, and an apparent desire to drive all the plant by as few ropes as possible, have resulted in the production of some very tortuous angular rope drives where it is often only with extreme difficulty and personal discomfort that the various ramifications of the rope can be followed.

There is no very great objection to a rope drive wandering about from room to room, nor even from building to building, provided proper precautions are taken. If at some period of its travels the rope passes through a gritty or dusty atmosphere, it should be protected in order to prevent the bad influence at this point affecting the drives to all other rooms or machines.

Where the rope is exposed out of doors, it is better to provide it with a protecting roof or, if this is not practicable, the rope should be treated frequently with rope compound or tallow. (See notes on care of ropes). Outdoor pulleys, shaftings, bearings, etc., should *always* be provided with a water-shed to protect them from rain.

A prolific cause of the poor service obtained from some of the pottery drives of the type mentioned is that very frequently, at some point in its extensive meanderings, the rope has to drive an absurdly small pulley for, say, a ventilating fan which, of itself, will absorb only a negligible amount of power, or perhaps to drive some small hoist or elevator by means of, again, a pulley which is much too small for the rope.

We have seen a $\frac{5}{8}''$ or $\frac{3}{4}''$ dia. rope which drives several rooms of "jiggers" and the "slip-house" pass over a 4″ pulley at one stage of its operations in driving a small ventilating fan. It must be realized that this single small fan pulley, though absorbing no power worthy of mention, is probably doing more to wear out the rope than several rows of "jiggers" by virtue of the excessive bending effect. Remember that *all* the rope has to suffer.

In order to obtain the necessary high speed for the fan, insert a small countershaft with a pulley of which the diameter is determined from the chart of "Minimum Advisable Pulley Diameters"; then, from this countershaft drive from a fairly large pulley on to a small one (it may be as small as desired) by means of a small endless rope about $\frac{3}{8}''$ dia. By using this small rope, which is quite sufficient for the power, the amount of wear is reduced and, the most important point, the main drive rope is spared entirely. A few of these small bands ready spliced could be kept handy for

replacing the old ones as these fail. The cost would be very slight, and in many cases the life of the principal driving rope would be doubled or increased even more if this principle were adopted universally.

There is not the slightest doubt that by increasing the number of drives and consequently limiting the bad effects of small pulleys or dusty and gritty rooms to one small drive and thus improving the conditions of others, a much longer aggregate rope life would be obtained and a very considerable saving effected.

The best system of driving to adopt would be to drive, at most, one building from one rope. Angular drives could thus be run from the engine house no matter where the latter were situated although a central position would be preferable. Each drive would be to a fast and loose rope pulley on a countershaft conveniently situated in the room or building requiring to be driven. From this countershaft the rope could be run round the room and returned to a tension pulley combined with the drive from the countershaft. By this method each room or building could be run independently and considerable power saved in consequence, but what would probably constitute the chief advantage is the fact that, should one rope fail either in the main drives to the building or the distributing drives to the machines, the stoppage which would consequently occur would be confined to that particular section only. Furthermore, the main drives would be spared from the more severe wear and tear imposed upon the lathe and jigger drives and would consequently have a greatly improved life.

With regard to mechanical details, we were profoundly impressed by the lack of attention which seems to be paid to such elementary things as the lubrication of pulleys. *Guide pulleys should be regularly and adequately lubricated* and the best means of doing this is by grease cups arranged so as *not* to go round with the pulley itself. Amongst the potteries where there are so many outside drives, this is of vital importance to the ropes. Guide pulleys are frequently hopelessly out of alignment. One guide pulley several degrees out of alignment may reduce by months the life of the rope passing over it.

Pulley diameters should be determined according to the chart to which previous reference has been made.

Pottery drives, in common with most of the more awkward angular drives, generally require weighted tension pulleys and slides. These slides, it was noticed, are usually about the same length, some 5 to 10 feet irrespective of the length of the rope on the drive to which they are attached. With some fairly short drives this allowance for stretching is quite adequate, but in numerous cases of long and severely conditioned drives, the allowance is insufficient with the result that the rope requires tightening much too soon and much too often. Tightening or "taking up" a rope reduces its effective life, so that too short tension slides in proportion

to the length of drive are indirect causes of the abnormally short service obtained from potters' ropes. In many instances, a longer tension slide is not possible, but in these cases particularly, and in all drives in general, a rope should be used which will not stretch rapidly. The weights provided on these tension pulleys in some cases appear to be too big. It should be borne in mind that the tension pulley is only to take up the sag of the slack side of the rope; the correct weight cannot be calculated for the complicated cases, such as are most potters' drives, and the best and simplest way therefore is to increase gradually the weight from zero until the slack is sufficiently taken up. *No more tension than this is necessary.*

Lathe Drives. Potters' lathes need some type of gear by which the operator can instantly reverse the direction of the drive. Various mechanisms have been devised to obtain this effect and those similar in principle to that shown by fig. 7 are by far the best. On no account should a method be resorted to which throws the driven pulley considerably out of alignment with the rope when the power is required.

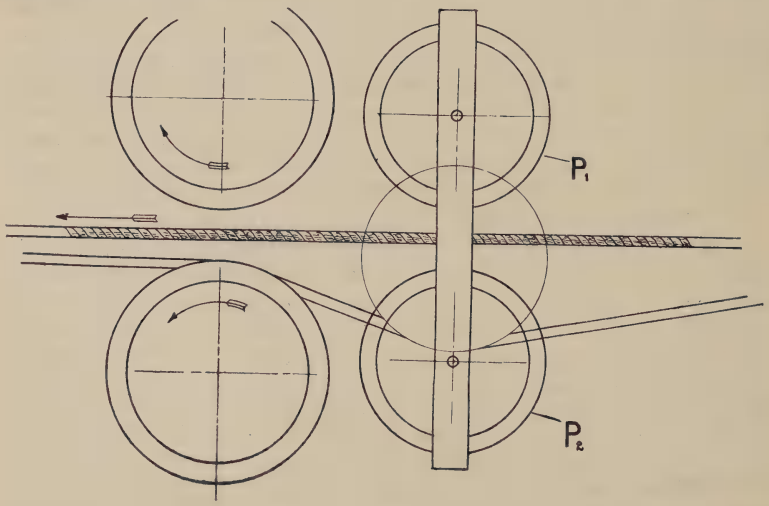


Fig. 7.

A common type of gear which has this defect is shown by sketch fig. 8. The amount of wear and damage to the rope by one of these mechanisms is prodigious.

The design shown in fig. 7 is, however, much more simple and efficient. The diameter of deflecting pulleys P_1 and P_2, fig. 7, should be determined as previously described.

"*Jigger Driving.*" The system of driving "jiggers" appears to be very much the same in every case. A single lap of the rope runs under the potter's benches and each wheel is provided with a

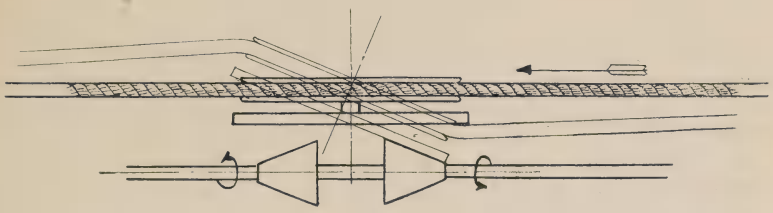


Fig. 8.

fairly large rope pulley low down on the spindle. A deflecting pulley can be made to force the rope on to this wheel driving pulley when desired. Provided the deflecting pulley moves in a horizontal plane, this method is not bad, *but the diameter of the deflecting pulley must not be too small.*

Serious defects occur when a supporting rope pulley happens to be close to the "jigger" as at (A) fig. 9. A side thrust will be borne by the rope on this pulley groove, resulting in excessive wear. Supporting pulleys are necessary, however, so that when they occur near a wheel spindle, they should be mounted on swivels to enable them to move to some extent in accordance with the rope.

A system of "Jigger" driving where the rope remains unaltered would probably constitute an improvement and it is tentatively suggested that a simple clutch could be utilized. The rope pulley bearing the internal cone of the clutch would rotate freely on the vertical spindle and the positive cone, possibly made of wood, could be keyed to the spindle, but capable of up and down motion. This could be arranged to fall out of engagement by its own weight and could be operated either by hand or foot, or by the knee.

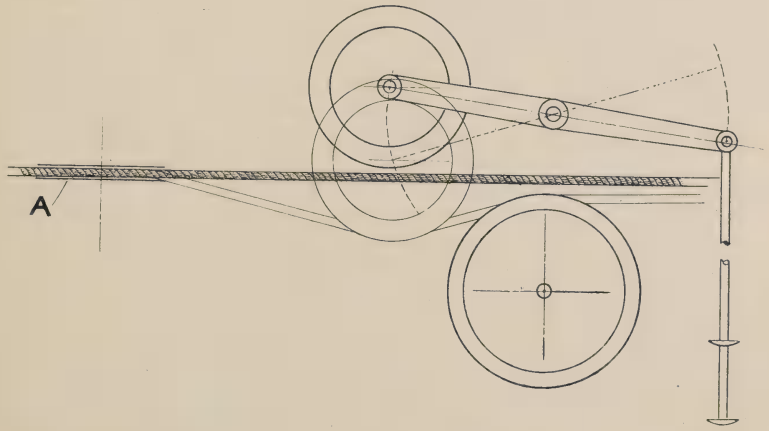


Fig. 9.

The rate of rope mortality amongst the potteries is appalling to one accustomed to the exacting conditious of the Textile Industry. It may be suggested that this is desirable from a rope manufacturer's point of view, but this is not true. A conscientious rope maker would rather see his ropes giving good satisfaction and their application consequently extending, than receive repeat orders every few months and know that he gets them purely and simply because "nothing else will do." By paying a little attention to the ordinary maintenance principles, viz.:—lubrication, protection, alignment, etc., appreciable economy in ropes can be effected in the potteries, and by going a step further and insisting upon correct design of pulleys and by following the suggestions put forward in this lecture, the author is convinced that the average life of pottery drives can be increased from four or six months to several years and that the amount of time lost due to rope failure could be very considerably reduced.

DISCUSSION.

Mr. F. Turner:—I have the greatest pleasure in proposing a hearty vote of thanks to Mr. Kenyon for his most interesting paper. I am afraid the subject of rope driving is one that I do not know very much about, and unfortunately, I am afraid the majority of the potters are in a somewhat similar position, although they *ought* to know something about it. After listening to Mr. Kenyon's paper, one is forced to realise how very inefficient rope drives are in the Potteries. I do not know whether the potters are entirely to blame for this. Surely the engineers ought to have been here also to have heard what Mr. Kenyon had to say. It would have been a good idea for the local engineers to have been present to hear Mr. Kenyon's criticisms. So far as the average potter is concerned, I am afraid he will have to sit down and digest the paper before he can grasp all that it really entails. The lecturer has certainly thrown out numerous hints, some of which must be quite plain to most people—points which are very often overlooked, or at least not considered of sufficient importance to trouble much about. If the paper has served no other immediate good it will certainly cause some people to be on the *qui vive*, in order to see that some things which were not previously done are done in future. The greatest good, however, will be done when everybody has had an opportunity of studying the paper in print. For my own part I confess I could not follow sufficiently the theoretical part of the paper on this first reading of it. It will, perhaps, not be so difficult when the paper can be studied at leisure.

There is one thing that is, perhaps, lost sight of in this district—although I do not know sufficient about the subject to be able to suggest that it may be altered—and that is, there are very few main drives in the Potteries that are rope driven. This may be a

mistake. Possibly a further reading of the paper will enable one to settle that point in one's mind. On the face of it it does seem to be a feasible move. If, for instance, you have three ropes on a pulley, and one rope smashes, you have still two left ; whereas, if you have only one belt and that smashes, one minus one equals nothing.

I think the paper has been an altogether interesting and valuable one. If we could only have had a few engineers present, its value would no doubt have been greater still, because, after all, one is entitled to expect from the engineers of the district some knowledge of engineering. One wonders sometimes when looking at some of the rope races on various potteries, whether that engineering knowledge has been clearly demonstrated, because usually these equipments have been erected not by the potters, but by engineers. Generally speaking, the size of the pulley and the number of guide pulleys has been determined by the engineer who has installed the drive. The potter has not known sufficient about the subject to give an opinion. Unfortunately, he has not sufficient knowledge of the subject even now. It is to be hoped that, as a result of Mr. Kenyon's paper, the potter may know a little more in the future about rope drives than he has known before.

Mr. F. S. Worthington :—I have much pleasure in seconding this vote of thanks to Mr. Kenyon, and in doing so, I would like to mention that I have seen a rope that was spliced by a man whom Mr. Kenyon sent down specially from Dukinfield. This rope has now been running, I think, about four months. The splicing is absolutely perfect, and I would defy anyone present to point out to me where the rope was spliced. I myself can neither see nor feel it. I know it is there, because I happened to see the job done. I think that the splicing of ropes is a point to which we all ought to give far more attention. The splicing of ropes is perhaps even more important than the quality of the ropes used, because we all know that a badly spliced jigger rope always leads to a trembling in the jigger head, which is very detrimental in the making of flatware, cups, and other jiggered ware, as it marks the ware badly.

Mr. Kenyon :—I thank you, gentlemen, for your appreciation of my remarks. I do not wish the proposer to be under any misapprehension. I am not blaming the potters for having inefficient drives, except in so far as, possibly, when one engineer tendered 50 per cent. higher than another, the job may have been given to the cheapest tender. That is my point. Although you are not responsible for the drive, you can get advice—and good advice—but will you pay for it ?

Mr. Turner :—I am afraid you do not always get it when you pay for it.

Mr. Kenyon :—What I feel about the matter is that it is false economy in the long run to have pulleys that are too small for these pottery drives.

MR. TURNER:—What are the shortest centres in which you can use a rope drive?

MR. KENYON:—I can give you an instance from actual practice where a rope drive of 360 h.p. has been installed with the pulley rims only 6″ apart.

MR. FIELDING:—What are the sizes of the pulleys in that case?

MR. KENYON:—I should say 15-ft. for the driving pulley and 3-ft. 6-in. for the driven pulley.

MR. LEESE:—In speaking of converting main drives, one of the biggest difficulties that we have to contend with in the Potteries is the shortness of the drives.

MR. KENYON:—We can drive any distance so long as there is sufficient clearance between the pulleys. I have actually replaced chain drives that were run at 3,000-ft. a minute with only 12″ pulleys, and with 15 h.p. to transmit 15 h.p.

MR. LEESE:—You have done that with ropes?

MR. KENYON:—Yes.

MR. LEESE:—What would you consider the best rope diameter, $\frac{5}{8}$ or $\frac{7}{8}$″?

MR. KENYON:—Each case must be considered on its merits; but, generally speaking, where you have rope trouble due to the pulleys being too small, it is advisable to overload a thin rope rather than have a thicker rope lighter loaded.

MR. LEESE:—The conclusion is that the rope must be set to the pulleys, or the pulleys designed to fit the rope.

MR. KENYON:—That is so. There is a relationship which must not be varied between the actual rope diameter and the diameter of the pulley. Velocity must also be taken into account. On these two factors—rope diameter and velocity—you determine your pulley diameter. What wears the rope out is bending under strain. The driving strain on a rope would have no wearing effect whatever, without the bending; it never exceeds $\frac{1}{20}$th of the breaking strain.

MR. LEESE:—A difficulty that we are up against in the Potteries is this: Suddenly a manufacturer will decide to extend a certain range or shops and directs that one rope shall drive the two places. After the lapse of some years, the probability is that a second engineer does this new work, and puts in his own particular size of wheel, which may vary in shape and size of groove. This gives a continual source of trouble and considerably shortens the life of the rope.

MR. KENYON:—As regards the splicing of ropes, which was referred to by a previous speaker, that is, of course, most important, and nothing but a practical demonstration will show what can be

done in the way of splicing. My firm has issued an illustrated leaflet on the subject, and we are also prepared, if this is desired, to teach any employee of a pottery manufacturer how to splice ropes to the best advantage.

Mr. T. Simpson:—Can Mr. Kenyon give us any formula or data by which we can ascertain the amount of weight necessary to put on any rope tension in order to get the maximum efficiency in driving power of the rope ?

Mr. Kenyon: —Before one can reply definitely to a question of this kind, one would have to take into account a number of factors. Assuming the pulleys to be efficiently lubricated, and that there is a certain definite friction at each pulley, one can determine the weight necessary to give efficiency. But one must know the number of pulleys and the number of jiggers or whatever other appliance one has to drive.

XXII.—The Refractory Silica Materials of South Wales with Special Reference to the Influence of Texture.

By W. R. R. Jones.

I. INTRODUCTION.

A. Among the most widely used refractories are those manufactured from silica rocks. The silica materials suitable for making silica bricks are abundant in South Wales and are extensively used. Nevertheless their properties and the exact factors upon which these properties depend, have not been studied with any degree of completeness. The properties of silica bricks are a resultant of variations which are often of opposite sign and varying at different rates.

One subject on which further investigation is required is the grading of the raw materials. The grading of the raw materials must obviously influence the texture of the manufactured bricks. Now it is upon the texture of the brick that the requirements which it has to meet are dependent. It has been generally affirmed that the finer the texture the less the corrosion and the greater the amount of conversion of the quartz into the lower specific gravity modifications in the initial burning, which, as is pointed out later, is an advantage. On the other hand, the coarser the texture the more refractory will be the brick and the more will it be able to withstand sudden and extreme changes of temperature. These examples are sufficient to point out the importance of the bricks possessing the correct texture.

Silica bricks were first manufactured in Europe in 1822 by Young. They were made from the Dinas stone quarried in the Vale of Neath, and the bricks themselves in use to-day are little better than those manufactured a hundred years ago. The silica bricks used in any one furnace vary solely as regards their shape, whereas a scientific use of our knowledge of the influence of texture and grading suggests the desirability of further differentiation in order to lengthen the life of different parts of the lining. For example, the bricks in the hearth should differ from those in the ports, and these again from those in the roof. The bricks in the hearth and on the banks should have as their chief property that of withstanding the penetrating action of slag. The bricks of the ports should withstand the corrosive effects of flue gases and the

cutting action of the flame. The bricks composing the roof should have as their main characteristic minimum contraction and expansion. As all these properties depend to no small extent upon the texture of the brick and the grading of its particles, and not so much upon the actual material, there are possibilities in the suitable grading of the raw materials.

Refractoriness alone is no criterion of the value of the brick, and an intelligent selection and application of refractory materials is of the utmost importance. Unfortunately, there is a tendency on the part of engineers to attribute all defects to insufficient refractoriness of the bricks.

Accordingly it appeared desirable that an investigation into the properties of the S. Wales silica materials should be made before attempting to produce by suitable mixtures of silica materials slightly varying in their composition, a mixture which will be self-binding, but not at the expense of refractoriness; or of producing a material which shall satisfy any one specification, (such as maximum compression strength, minimum slag penetration, minimum effect from corrosive flue gases, maximum refractoriness under varying conditions, minimum expansion or contraction, capability of withstanding sudden and extreme variations of temperature.) It is extremely doubtful (probably impossible), that one material or any single mixture of materials will satisfy all or most of these specifications, as one property has to be sacrificed at the expense of others.

Unless intelligence is employed in the application and use of silica bricks, and of firebricks in general, a really excellent brick is liable to be condemned unjustly. This has been rather frequently the case. A case that has come under my own observation will serve as an example. At a certain colliery equipped with a battery of coke ovens a new lining was installed in a few of the ovens. The silica bricks bought were among the best manufactured, and consequently expensive. They wore away at an alarming rate, and did not stand usage nearly as well as the old and much cheaper brick lining. The texture of the bricks was at fault. The coal coked was ordinary Welsh bituminous coal, but with rather more than average amount of salts which have a great corrosive effect upon the bricks. The refractoriness of the brick was high, but the texture was not such as to give the minimum corrosion.

The bricks in a coke oven should possess a close surface as coarse open bricks are more readily attacked. On the other hand, the centre and rear of the brick should have a fairly open and porous structure in order to withstand the sudden changes in temperature, especially if quenching the coke is begun inside the oven, always a risky but sometimes necessary procedure in the older form of coke oven—the bee-hive or non-byproduct retort oven.

In the selection of a silica brick for any particular use it is necessary to examine carefully the conditions to which the brick

is likely to be subjected. Among the points that need consideration are[1]:—(1) The highest temperature which is to be attained and whether the temperature is maintained steadily, or whether it fluctuates. (2). If flames play on the brick, will they be of an oxidising or reducing nature? (3). Will the brick have to withstand sudden and extreme changes in temperature? (4). Will it have to withstand the corrosive action of slag, metals or metallic oxides or flue gases and fluxing action of any sort, *e.g.*, limestone or other fluxes and the action of the solid fuel, if any? (5). The mechanical treatment to which the brick may be exposed. (6). The mechanical strength necessary, *e.g.*, if the brick has to be transported over long distances by rail or sea it should be strong enough to withstand to a reasonable extent attrition, storage, etc. By a suitable grading of the material it is possible to manufacture a brick whose texture shall be such as to specialise in one of these varying conditions. Metallurgical practice in S. Wales will be in the near future probably extensively developed especially in the ferrous industry. No special steels are as yet manufactured (to any extent), and electric smelting will probably become important (especially if the River Severn should be dammed and power obtained from the tidal energy). To meet these developments which necessitate higher working temperatures and higher refractoriness of our bricks, if use is to be made of the abundantly occurring silica rock, some means must be obtained of manufacturing a strong brick by means of a bond which shall not lower the refractoriness and other properties.

B. The Materials used. The chief firms manufacturing silica bricks in S. Wales were applied to for samples of the raw material they used. They willingly responded and gave as much information as they had, which was very little. The material sent was in the condition in which it leaves the quarry, *i.e.*, undressed except that it had been broken into small pieces for transport. They also sent samples of highly siliceous sands used in the final layers of the lining for the hearths and banks of open hearth furnaces and for fettling. The material employed represents that used in the manufacture of approximately 90% of the silica bricks made in S. Wales. Each material used in these experiments was analysed and where the results showed no great disparity from those supplied by the manufacturers, the average analysis of the latter is taken to represent the rock in question.

The ultimate analysis of the materials is given in the table on p. 361.

Numbers 1, 2, 3, 6, 7, 10, 11 and 12 are analyses of the rock proper, whilst Nos. 4, 5, 8 and 9 are analyses of the siliceous sands used. No. 13 is the published analysis of the brick manufactured from the material of No. 1.

[1] Searle *Refractory Materials*.

Sample No.	Silica	Alumina	Iron Oxide	Lime	Magnesia	Potash soda	Titanium Oxide	Loss on Ignition
1	98·55	1·54	0·53	0·20	0·19	0·65	—	0·40
2	97·30	1·00	0·80	0·20	0·20	—	—	0·40
3	93·50	4·00	0·70	0·35	0·40	—	—	0·80
4	93·50	1·60	2·80	0·05	—	0·30	—	1·30
5	84·0	9·80	1·90	0·70	0·20	0·24	—	2·90
6	99·14	0·30	0·17	—	0·04	0·07	0·02	0·30
7	97·74	1·01	0·50	0·02	0·04	0·05	0·14	0·50
8	83·31	9·22	0·43	0·86	0·14	1·03	—	1·96
9	98·16	0·83	0·04	0·27	0·05	0·08	—	0·55
10	94·75	2·01	1·19	0·90	0·25	0·18	—	0·70
11	97·40	0·20	1·40	0·15	—	—	0·15	0·70
12	93·65	3·85	0·75	0·65	0·38	0·08	—	0·75
13	95·30	1·52	0·52	1·76	0·19	0·64	—	—

The analyses are interesting and show that on the whole the material used for making silica bricks in S. Wales is practically identical as regards chemical composition. The silica averages about 95% and in the silica rock proper the alumina content is under 2% ranging from 0·2% to 1·5%. The iron content exceeds 1% only in one case. The lime, magnesia and alkali content are low throughout. It is noted that No. 12 and No. 3 are in close agreement with each other, but differ to an appreciable extent from the remainder of the silica rocks—the chief difference is found in the high alumina content. No. 12 is known in the trade as a "quartzite," and No. 3 as a "ganister." Both, however, have an equal right to the latter term.[1]

The siliceous sands show a greater variation in chemical composition. It is interesting to note that No. 9, the most pure of the sands, is quite white in colour.

II. THE GEOLOGY AND PETROLOGY OF THE RAW MATERIALS.

Previous Work. The mode of occurrance of the silica rocks used at present in S. Wales is described in a Memoir published by the Geological Survey, Vol. VI. of the Special Reports on the mineral resources of Great Britain (second edition, 1920), and also in a paper to the Ceramic Society, Vol. 18, by Howe. Consequently, only a brief mention is necessary in this paper.

[1] The nomenclature of silica materials used and the bricks made from them are discussed inMemoirs of the Geological Survey (special reports on the mineral resources of Great Britain) Vol. VI., p. 2 and 3.

Scott[1] states that most of the suitable rocks are of Palæozoic (Carboniferous) age; differences in the rocks lie in amount of impurity or variation in size and shape of the grains which should be angular. Lange in "Tonindustrie-Zeitung" on "The investigation of quartzite and determination of its availability as a refractory material for the manufacture of Dinas bricks," says that useless quartzites show interlocking grains lying compactly against each other without any amorphous or crypto-crystalline cementing material. All useful quartzites have the single quartz grains separated from each other lying embedded in a groundmass or basal cement." These views are not supported by McDowell[2] in an examination of the most important American quartzites which have no groundmass or cement, but consist essentially of interlocking quartz crystals. Endell[3] on the constitution of Dinas bricks affirms that those quartzites are useless which in microscopical examination show in the individual quartz grains a wave-like extinction on slowly revolving the stage of the microscope. An interesting account[4] of the petrography of silica rocks is given in a recent memoir. Pohl in a paper on the industrial use of quartz glass, etc., points out the benefit of using cherty material for making "Dinas" bricks. This conclusion is supported by Wernckie and Wildschrey, who also state that the quartz grains should be cemented in a groundmass of amorphous or cryptocrystalline silica with little or no mica. They, however, advocate the use of quartzites with mostly rounded grains of different sizes.[5]

The age and mode of occurrences of the raw materials. In S. Wales the silica rocks used for the manufacture of Silica bricks are all obtained from the Millstone Grit of the Carboniferous System generally from the basal section sometimes called the Basal Grit. The Millstone Grit outcrop skirts practically the whole of the South Wales Coalfield. It is continuous with varying breadth from Kidwelly through Llandebie, the Black Mountain, Penwyllt, Vale of Neath (Glyn Neath, Penderyn and Hirwain) Dowlais, Trefil, (North of Sirhowy–Tredegar), Clydach, Blaenavon and Abersychan — a total distance of approximately 140 miles. On the Southern margin of the coalfield the outcrop is not so wide. It runs almost parallel with the coast line from Risca through Taffs Well and with a slight break to Pyle. It then sweeps across St. Brides Bay, being concealed in parts by the waters of Swansea and Carmarthen Bays, and appears again in Pembrokeshire. The outcrop in Pembrokeshire has not been extensively worked; only one quarry at Templeton near Narbeth is noted. The reserves are enormous, even in the quarries which are being worked. Large areas of the outcrop

[1] TRANS. **17,** 459, 1918.
[2] *Trans. Amer. Inst. Min. Eng.*; *Bull.* 119, p. 2001, 1916.
[3] *Stahl und Eisen*, **32,** 392, 1912.
[4] Vol. XVI. of the special Reports on Mineral Resources of Great Britain, published by the Geological Survey.
[5] *Stahl und Eisen*, **33,** 235, 1913.

have not yet been worked. The silica sands which are used for furnace hearths, fettling, etc., are obtained by digging the sandy detritus produced by the weathering and disintegration of the Millstone Grit rocks and those of the old Red Sandstone. It is noted that a fair quantity of silica sand used in furnaces is not naturally occurring, but is derived from crushing the silica rock material itself. The naturally occurring sand contains a more or less larger amount of argillaceous material easily removed by washing. Such sand is often used as mortar for setting the silica bricks and is not washed before use.

Microscopic characters. The silica rocks are all very fine grained and of a light buff colour, varying from a pale purplish grey to light brown. Iron staining is seen on the surface probably due to iron waters perlocating the joints of the stone while in the quarry—the interior of the stone shows no iron staining. On the surface of some of the rocks are small long thin six-sided crystals of quartz. Minute specks of iron oxide and carbonaceous material may be noticed. The grains of quartz are all more or less angular. Some specimens are slightly micaceous.

The silica sands vary in colour from a light brown ochre colour in samples No. 4 and No. 5 to an almost pure white in Sample No. 9. The sands are composed of flour and quartz grains of heterogeneous size varying from 0·1 m.m. to 5 m.m. or larger quartz and chert pebbles up to $\frac{1}{2}$ inch diameter. The sands often contain fragments of the silica rock which have to be crushed before use. The grains of the sands are more rounded than those of the silica rock and often occur as lumps which powder and break down between the fingers.

Microscopic characters. Chemical and pyrometric analyses are essential but do not give conclusive evidence as to the suitability of silica rocks for brick making. Both a chemical and pyrometric analysis give refractory qualities. A microscopical analysis is necessary as it gives the nature of the impurities, the shape and size of the grains, etc. The microscopic examination was carried out on thin sections of the rocks. A method of examination by reflected light was tried but was not found to be as convenient as examination by transmitted light.[1] The rocks were found to be practically identical, but for small variations, such as grain size, etc.

No. 1. This is a typical quartzite consisting of quartz grains of an average size of 0·3 m.m. ranging from 0·4—0·2 m.m. There are occasional grains of crypto-crystalline silica-chert, of about 0·2 m.m. average size which are easily recognised by their darker and pitted appearance. The grains of quartz are angular and interlocking. They are cemented by secondary silica most of which is in optical continuity with the original grains and generally granular. The grains of quartz are occasionly faintly stained brown by ferruginous material and contain the usual inclusions. The secondary silica is clearer.

[1] The rock was cut on a revolving wheel fed with carborundum powder and the surface polished with carborundum powder of varying degrees of fineness, finishing on a revolving pad of selvyt cloth and diamantine. The polish obtained was good, but did not reflect the light sufficiently well using a metallographic microscope fitted with a prism reflector and a condenser.

Thin flakes of white mica are present, although very rare, and small fragments of opaque material which are probably the accessory iron minerals. The extinction is straight, *i.e.*, not wave-like.

No. 2. Similar to No. 1, except that the grains are large and small interlocking the former showing more inclusions. Minute cracks in the quartzite are filled with iron material. (See Fig. 1).

No. 3. The grain size of the quartz is more irregular. There are some larger grains of 0·9 m.m. diameter both of quartz and of chert, associated with interlocking grains of 0·5—0·4 m.m (See Fig. 2).

No. 6 is similar to No. 1, but contains less chert. The impurities are chiefly small specks of ferruginous material. (See Fig. 4).

No. 7. Some of the quartz grains are much broken up.

No. 8a. Is a thin section of the largest sized stone in the sand sample No. 8, and is identical with sample No. 1. (See Fig. 6).

No. 10 is a fine grained quartzite, the grains of quartz being about 0·2 m.m. average. There are more impurities present than in sample No. 1, weathered felspar and laths of mica are seen. Thin streaks of carbonaceous matter are present. The opaque iron accessory minerals do not appear to be much in access of that in sample No. 1. (See Fig. 3).

No. 11 is a very fine grained material of average size 0·1—0·15 m.m. The amount of chert is small, but the opaque iron minerals larger than in sample No. 1.

No. 12 is a fine-grained weathered material with much corroded felspar and a comparatively larger amount of carbonaceous material. Little chert is seen to be present. (See Fig. 5).

Figs. 1–6. The photo-micrographs given were taken in open light, using a 1″ objective and the diameters noted. They are all more or less typical photographs of the respective rocks which have been described in thin section above. A large grain of chert is seen in sample No. 3, and flakes of mica in Nos. 10 and 6, in the centres of the fields. The angularity of the grains is noticed in each photograph and the relative small amount of non-siliceous material. The difference in the grain size of some of the rocks is clearly shown by comparing No. 6 and No. 7.

Conclusions as to the essential characters. The rocks examined are typical quartzites with comparatively little impurity. The average size of the grains is from 0·3 m.m.—0·4 m.m. The quartz grains are angular and embedded in a groundmass or cement of amorphous or crypto-crystalline silica which is in optical continuity with the quartz grains. The extinction of the quartz grains is not wave-like but straight. The impurities are small amounts of mica, weathered felspars and iron ores.

From the considerations of these rocks it is shown that materials which are suitable for the manufacture of silica bricks should be quartzites which have (1) little impurity, *i.e.*, non-siliceous matter. (2) angular grains which are set in a siliceous cement in optical continuity with the quartz grains. (3). Should possess some chert or crypto-crystalline silica. (4). Should not possess a wave-like extinction of the quartz grains. These conclusions are supported by those of Scott, Lange, Endell and Pohl quoted above. These rocks, however, show that the conclusions of McDowell and Wernicke and Wildschrey are erroneous.

Fig. 1.

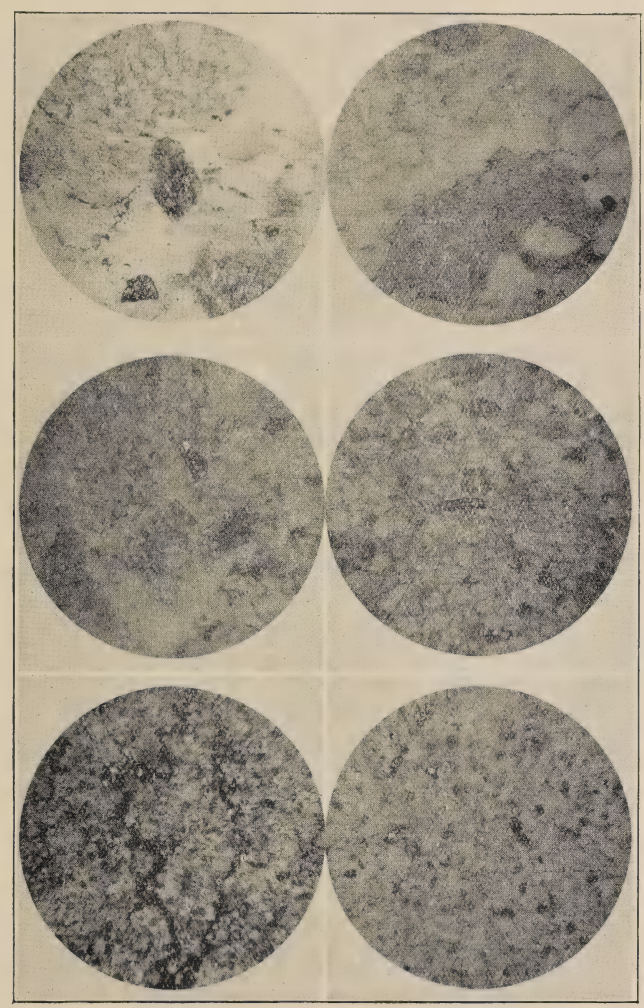
Fig. 2.

Fig. 3.

Fig. 4.

Fig. 5.

Fig. 6.



Photomicrographs

Fig. 1. (Sample 2) × 30 diam.
Fig. 2. (Sample 3) × 30 diam.
Fig. 3. (Sample 10) × 15 diam.
Fig. 4. (Sample 6) × 15 diam.
Fig. 5. (Sample 12) × 15 diam.
Fig. 6. (Sample 8A) × 15 diam.

III. THE MECHANICAL ANALYSIS OF THE MATERIALS.

By the texture of a material is meant its size of grain or its fineness. It is pointed out later that texture exerts an important influence upon many properties of silica bricks. Consequently, an accurate knowledge of the grade of the raw material which is to be made into bricks is essential.

The terms gravel, sand, silt and mud are not precise definitions of various materials as is commonly thought to be the case, but are relative terms denoting the size of the grains or the grades of any particular material. For example, all grains of size greater than 2 m.m. diameter belong to the gravel category, and sizes from 1 m.m. to 2 m.m. to the coarse sand grade and so on until the finest particles of size less than 0·01 m.m. which are termed the clay or mud grade.

The object of the mechanical analysis is to sort the grains of any material into groups or grades so that in each grade the particles are of a specified size. The general importance of mechanical analyses is being slowly realized. Comparatively little work has been done in this branch, and the work of Boswell[1] on mechanical analysis and its advantages is very noteworthy.

In the case of refractory siliceous sands the advantage of grading is obvious, but in the case of the silica rock itself mechanical analysis must be cautiously applied. The grade of the material derived from the mechanical crushing of the rock depends upon many factors, amongst which are the strength and hardness of the rock itself, the efficiency of the grinding machinery, the force of the grinding, wet or dry grinding, whether the rock has been allowed to "weather." etc. The result of this is that the grading is comparative and of a qualitative rather than a quantitative nature. However, the mechanical analysis of the ground material is useful in giving an accurate idea of the texture and consequently of the ultimate behaviour of the brick manufactured from the crushed rock.

It is perhaps of sufficient importance for practically all purposes to determine the percentages of any sample which will pass through standard sieves—those of the Institute of Mining and Metallurgy scale being admirable for the purpose. But if it is desired to measure the size of particles below a diameter of 0·25 m.m. about, a more delicate means of sizing is necessary. Screening or sifting may be resorted to without much fear of error for coarse sand and gravel, but for very fine material the errors become too large and the sieving becomes too long an operation, with liability to contamination and want of accuracy. The finer the sieve the more likely are the apertures to be irregular in size, and for the finest material the apertures of the sieves cannot be made sufficiently small.

[1] Memoirs on British Resources of Sands suitable for Glass Making, 1916 & 1917.

Mechanical analyses were carried out on each sample under as near as possible the same conditions. In the mechanical analysis of the crushed silica rocks, the portion which passed the I.M.M. sieve of 30 mesh *i.e.*, 30 apertures to the linear inch, was reserved for the finer method of grading called elutriation. The diameter of the aperture of the 30 sieve is 0·424 mm. so that all material less than 0·424 mm. diameter was subjected to elutriation. In the treatment of the hearth sands no crushing is necessary and the material is merely disintegrated by gentle rubbing with the fingers in order to keep as far as possible the natural physical condition of the grains.

In the treatment of the silica rocks the rock was gently pulverised by the pestle acting in a vertical direction in the mortar, and not in a horizontal circular direction which gives a grinding rather than a pulverising action and so destroys the angularity of the grains. To keep the percentage of very fine dust as low as possible, the pestle is not allowed to drop from a height of more than 3 inches on to the rock. This makes the crushing a very tedious and long process which is unavoidable if any comparison between the rocks is desired. The material is crushed until sufficient (about 20–25 grammes) is passed through the 30 mesh sieve.

The apparatus which was used is a modification of Crooke's elutriator. The apparatus and method of using it is described in the "Memoir on British Glass Sands" (Boswell, 1916). The apparatus is simple to use and enables a mechanical analysis to be made rapidly, all the grades required being separated at the same time. The sizes of the grains of each grade were found by direct measurement using a micrometer scale graduated in tenths and hundredths of a millimetre attached to the microscope.

The following were the average sizes in diameters of each grade ; Grade 1, 0·45 mm. ; Grade 2, 0·25 mm. ; Grade 3, 0·10 mm. ; Grade 4 is the finest material, estimated by difference and is composed of heterogeneous sized grains of less than 0·10 m.m. diameter. These grade sizes seem high because the material was passed through a 30 mesh standard I.M.M. scale sieve. The diameter of the aperture of this sieve is 0·424 mm. The difference is probably due to an optical effect. Boswell states[1] "the average diameter obtained by microscopical measurement has usually too high a value. Particularly is this the case with certain crushed rocks among which is quartz. Quartz although it has no cleavage tends to crush into a flaky form and elutriation products always appear when examined under the microscope to be coarser than they really are."

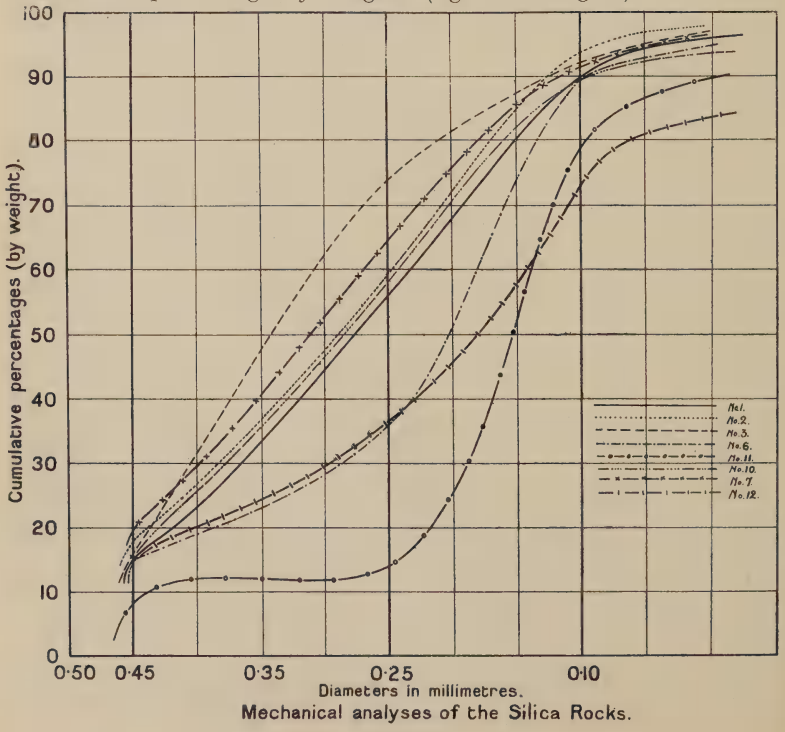
The mechanical analyses of the raw materials so determined are as follows :—

[1] Memoir on British Glass Sands, 1916 p. 5.

Sample No.	Grade 1.	Grade 2.	Grade 3.	Grade 4.	Mean crushing strength to nearest 5 lbs. per sq. in.
1	14·8%	41·0%	33·8%	10·4%	210
2	17·3%	40·9%	35·4%	6·3%	215
3	15·3%	57·9%	18·7%	8·1%	165
4	18·5%	27·9%	31·0%	22·6%	160
5	2·6%	14·75%	48·74%	33·7%	125
6	16·0%	19·75%	53·5%	10·8%	100
7	19·1%	44·2%	28·4%	8·2%	120
8	13·8%	21·0%	43·0%	22·2%	1010
9	23·75%	41·75%	25·9%	8·6%	220
10	15·4%	43·0%	31·3%	10·4%	185
11	7·6%	5·9%	64·8%	21·7%	235
12	15·5%	20·75%	36·0%	27·75%	260

The connection between the grading and the crushing strength is discussed later.[1]

The graphical expression of the results in the form of curves is to be regarded as an approximation only, serving to visualise the lists given the table and should be studied only with the table. The horizontal ordinates of the curves are the mean diameters in millimetres of the grades.[2] The vertical ordinates denote the cumulative percentage by weights (fig. 7 and fig. 8).

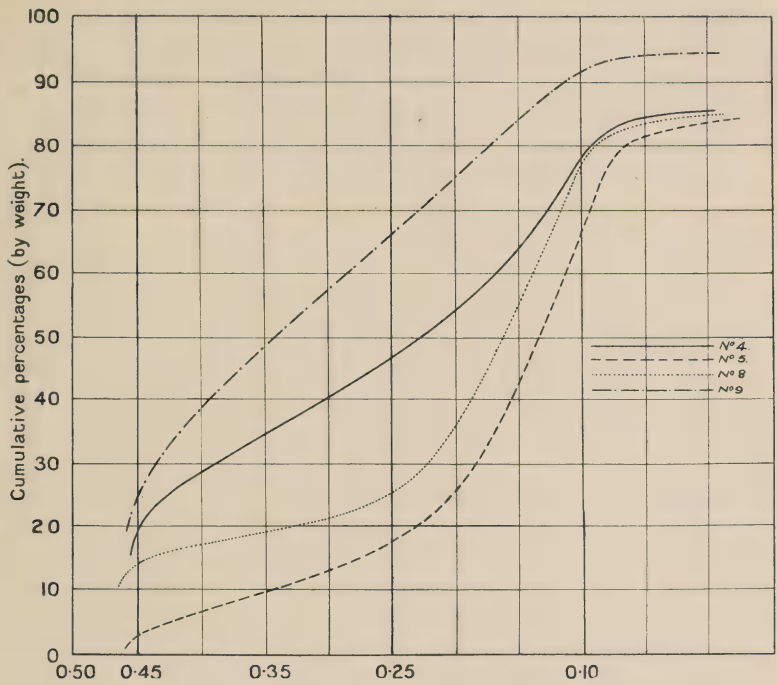


Mechanical analyses of the Silica Rocks.

Fig. 7.

[1] (See p. 374).

[2] The effect of the apparent slightly increased size is common to all the grades and materials.



Mechanical analyses of the Silica Rocks.
Fig. 8.

Discussion of the mechanical analyses. The curves of the silica rock materials, *i.e.*, the crushed rocks are very constant, particularly so when it is remembered that the crushing, although as uniform as possible, was not done by means of a standardised machine. The curve given for sample No. 11 is not in close agreement with the other curves. Some explanation is given on reference to the microscopical examination and to photo-micrograph No. 5. It is observed that this material is very fine grained, the average size of the quartz grains being about 0·1 m.m. A similar explanation is given for the curve of sample No. 12. The curve given by sample No. 3 can also be somewhat explained by the result of microscopical examination. A thin section of this material points out a great irregularity of grain size.

The mechanical analyses of the silica sands show on the whole a larger amount of material of the finer grades than the mechanically crushed silica rocks. The grading of the sands differ in each case but each sand has almost a regular or constant grade.[1] The regu-

[1] The curves for the silica sands are practically parallel.

larity of the grading of the raw materials, which is best shown by means of the curves, affords some further evidence of the similarity of the materials used in S. Wales for manufacturing silica bricks.

IV. THE CRUSHING STRENGTH OF THE MATERIALS AT THE ORDINARY TEMPERATURE.

Introduction. The mechanical strength of silica firebricks needs attention, since the bricks must have sufficient strength to bear the superincumbent weight in a mass of brickwork which together with the thermal expansion of the brick may produce considerable pressure. This resistance to crushing is much lessened at high temperatures of the furnace. It has been stated often that the tests should be made at the working temperature. Much is to be said in favour of testing bricks at high temperatures, but even then it is not a fair test inasmuch as the bulk of the brick in the furnace is at a much lower temperature than the face exposed to the furnace. In practice silica bricks rarely fail on account of low crushing strength which is generally well above ordinary requirements. The crushing strength of the cold brick gives a fair criterion of the behaviour of the brick at the higher working temperatures. If the brick withstands the superincumbent pressure when built into the furnace before the furnace is fired, the chances are that it will stand the weight at the working temperature. Support is given the face exposed by the much colder bulk of the brick and the whole brick is supported by the masonry round it. What is of importance is the good laying of the brick, and the general shape, and the cement used which should have as near as possible the same thermal expansion as the brick.

Where good mechanical strength is required is in the prevention of excessive loss in transport, etc. Many brick works are at some distance from the steel and iron works; and to compete in foreign trade obviously a strong reliable brick is required. The Institution of Gas Engineers demands in its specification that silica bricks shall withstand a crushing strain of not less than 1,800 lbs. per square inch when applied to the whole brick placed on end in a machine giving a vertical thrust. The majority of users consider this too lenient a test, demanding a crushing strength about 150 tons to the square foot (vide Searle "Refractory Materials," p. 192) Le Châtelier and Bogitch[1] consider that a crushing strength of 100 Kilogrammes per sq. cm. (*i.e.*, 1,422 lbs. per square inch), seems to be the minimum for preventing excessive loss in transport, etc.

The crushing strength of silica bricks depends upon many factors, the chief being the chemical composition, the texture and uniformity of the brick, and the amount of fused material which binds the particles together, and, therefore, it is related to the tem-

[1] *Rev. Met.*, **15**, 510, 1918.

perature and length of burning. Consequently great care is required in grinding the rock, in its admixture with water,[1] and the treatment which the moulded brick receives in the kiln.

The following crushing tests were made on the raw material with no binding material of any kind. The bricks were prepared in the manner described in appendix (1) of a length of 1″ approximately so that the tested brick was within narrow limits a cube of 1 inch.[2]

This size was adopted as being best for the convenience of the testing machine and for calculation and comparison.[3] The size of the brick when moulded was slightly under 1″ to allow for expansion in the firing. Six bricks at least were made from each material. The bricks were made at the same time, dried and fired together in the same furnace.

The firing was carried out with every precaution, the rate of heating being not more than 100°C. per hour and above 900°C., not more than 50°C. per hour, checked by pyrometers. The temperature reached averaged 1,350°C$\pm$.20° and was kept there for seventy-two hours. The temperature at night-time was not under control, but as the bricks were in the furnace together, any alterations were common to all, and did not affect the results in a comparative sense.

In order to reach this high temperature in an ordinary laboratory furnace conduction and radiation losses must be as low as possible. All holes, except a peep-hole for taking the temperature, were luted up thickly with fireclay and a layer of sand placed on the top of the outside of the muffle. The temperature was well maintained and in one or two instances actually reached 1,410°–1,420°C. Owing to the increased pressure of gas in the night time when there is less gas being used in the town, the temperature was probably nearer 1,400°C. than 1,350°C. This temperature (1,350°C.) is lower than the average finishing temperature of works practice in S. Wales which is about 1,450°–1,500°C. depending upon the class of rock used.

The furnace was cooled as slowly as possible to prevent cracking of the bricks, the gas at the main being turned down very slowly and the air regulators being closed gradually. The gas taps were left full on so that cooling was fairly uniform from front to rear of the furnace. Two days were given the furnace to get absolutely cold. The bricks were taken out and examined for any flaws which meant the rejection of the brick. The bricks were gauged to a cube of 1 inch dimensions. Only in a few cases was it necessary to grind the brick down as the changes in volume due to the burning

[1] *Rev. Met.*, **15**, 487, 1918. Philipon states that the crushing resistance is greatest on adding to the ground material the maximum amount of water compatible with good manufacture without deformation of the brick on removal of the mould.

[2] A difference of hundredths of an inch.

[3] There is a general tendency of making tests on concrete, cements and mortars on cubes of 1″ dimension.

are not sufficiently large on the 1-inch dimensions to warrant any grinding if the brick was well made.

Grinding down was only resorted to when unavoidable, because the breaking of the outer skin probably lowers the result a little, owing to its peculiar nature. The outside of the brick is subjected to a slightly higher temperature than the interior, resulting in slightly increased fritting of the grains on the surface. The skin is thus probably somewhat stronger than the interior of the brick.

When grinding was necessary, it was carried out gently, using fine grade carborundum powder on a thick slab of plate glass, no water being used. The bricks were stored in a dry cupboard.

Description of the fired bricks :—

No. 1. Dark brown in colour with black specks of magnetic oxide of iron Fe_3O_4, uniform texture and compact. Withstood abrasion fairly well.

No. 2. Similar in colour to No. 1, with fair number of black patches of iron oxide, uniform texture, did not withstand abrasion quite so well as No. 1.

No. 3. Lighter brown in colour, withstands abrasion as well as No. 1. One of the bricks showed tendency to spalling (not shown in No. 1 and No. 2.)

No. 4. Pale brown brick with no "scabbing" (black specks of iron oxide) even texture, no spalling and withstood abrasion well.

No. 5. Very similar to No. 4, with a few scabs.

No. 6. Little scabbing, texture uniform, colour was a dark brown. These bricks were easily abraded.

No. 7. Darker brown than No. 6, with more scabbing, even and compact texture, withstood abrasion better than No. 6.

No. 8. Dark Brown and very compact—in every way the best brick made. The edges were well defined, and the bricks withstood abrasion exceedingly well.

No. 9. Quite white in colour, compact, a tendency to spall, two bricks spalling and breaking, giving a very straight fracture (the broken bricks were uniform in texture).

No. 10. Pale brown in colour, scabbing not so pronounced as in No. 1, did not withstand abrasion very well.

No. 11. Medium brown colour ; tendency to spalling and easily abraded ; texture uniform.

No. 12. Fairly dark brown in colour, very compact and uniform, withstood abrasion well.

No. 13. This specimen was a piece of a manufactured brick bonded with lime and well-fired to 1,460—1,500°C. ; very coarse structure with large grains of crystalline silica 5 mm.—8 mm. in a pale yellow groundmass ; slight brownish coloured patches (not scabbing) of fair diameter were noticed on the surface. Very hard and compact brick. By grinding on an emery wheel revolving at high speed a cube of 1″ dimension was obtained and tested.

The compression tests were carried out on a small Riehlé 30,000 lb. machine which acts on a multiple lever system. This machine is capable of accurate adjustment and is simple to manipulate. It is power driven, thus giving more accurate results than if hand driven. The pressure acts downwards and was applied slowly, each addition being counterpoised at once. To compensate against any possible slight non-parallelism of the test-piece, pieces of card board about 2 inches square and $\frac{1}{8}$th inch thick were placed above and below the brick in the machine. A satisfactory test result is one in which the brick fractured showing typical pyramidal

cleavage and shear stress. Bricks not showing this "pyramid" were rejected.

The results of the tests are as follows[1] :—

Sample No.	Results in lbs. per square inch.						Mean lbs per sq. inch (to. nearest 5 lbs.)
	1	2	3	4	5	6	
1	200	185	230	225	210	—	210
2	225	200	215	225	—	—	215
3	175	155	160	—	—	—	165
4	170	150	165	155	—	—	160
5	120	130	120	125	—	—	125
6	100	90	115	100	—	—	100
7	135	125	110	115	—	—	120
8	985	1120	1090	1010	1010	990	1015
9	225	215	220	230	—	—	220
10	180	185	200	190	—	—	185
11	250	230	225	245	220	—	235
12	255	265	250	260	—	—	260
13	2360	2395	2385	2370	—	—	2380

The mean results show a wide variation. Differences of chemical composition and in the preparation of the bricks may have affected the results to a slight extent only.[2] The wide variation is due to the difference in the texture of the materials.

The results should be studied in conjunction with the results of the mechanical analyses.[3] Sample No. 3, which one should expect to be stronger than sample No. 1, gives a comparatively low result. The chemical composition of sample No. 3 shows a high percentage of alumina which with silica forms a "clay" substance, imparting to "ganisters" their property of "self-binding." This should warrant the assumption of a higher crushing strength in these experiments than the ordinary silica rock used in brick making. On an examination of the mechanical analyses of the material used in these experiments, it is noticed that the grading of sample No. 3 is very different from that of sample No. 1. The former material is seen to possess a coarser grade than the latter, and there is not sufficient finer grade material in No. 3 to permit a true comparison.

That the mechanical analysis plays an important part is further emphasised by a comparison between samples No. 3 and No. 12. Their chemical analyses are practically identical, but their crushing strength results are very different. By comparing the grading of the materials used an explanation is obtained. Sample No. 12 is shown as having a larger amount of fine grade material with a

[1] Four fairly consistant results were desirable in taking the mean.
[2] The materials are almost identical in chemical composition and as far as possible, the method of making and burning the bricks was the same in each case.
[3] The mean crushing strengths are also entered in the table of mechanical analyses on page 368.

consequent increase in strength. The result given by the test pieces made from sample No. 8 is the highest. This material is a hearth sand and two factors account for this high result. There is a relatively large amount of fine grade material; and the chemical composition reveals the presence of a large amount of argillaceous cementing material as shown by the high percentage of alumina. On the whole it is seen that the finer the grade of the material the higher the compression strength of the bricks made from that material. It must be noted that these figures, although low for a commercial brick, were obtained from material without any added binding material. The results, however, are sufficient to show the importance of careful grading of the material.

IVa. THE CONNECTION BETWEEN CRUSHING STRENGTH AND TEXTURE.

The connection between grain size or texture and the compression tests in the cold is worthy of notice and a series of tests were carried out on the same material using different sizes of the grains. The bricks were made, fired, and tested under the same conditions.

Philipon (Vol. 15, 1918, Revue de Metallurgie) asserts that the crushing strength of silica bricks increases with the fineness of the grain of the quartz, and that all kinds of quartz can give bricks of good crushing strength if they are made of extremely fine-grained material. He further states, that as the expansion of each kind of silica is practically the same when reduced to a very fine powder, any kind of crystalline silica can be used in the state of flour for making bricks.[1] This seems to be much too sweeping a statement. It is an acknowledged fact that bricks which have to withstand sudden and extreme changes of temperature should not be too fine grained. The coarser grained the brick the more able it is to withstand sudden and large variations of temperature.

The material used was sample No. 1. The material was pulverised and sieved using the I.M.M. standard scale sieves. Four grades were used, 30, 60 and 80 mesh sieves, and the coarsest grade is the material which passed a sieve of 25 mesh to the inch, but remained on the 30 mesh sieve. (The 25 mesh sieve was not a standard sieve so the coarsest material is just larger than the material passing the 30 mesh sieve.)

The sieve scale of the I.M.M. and dimensions of the grains are:—

Mesh, *i.e.*, apertures per linear inch	Diameter of Wires		Diameter of aperture		Screening Area per cent. holes
	Inch	Mm.	Inch	Mm.	
30	0·0167	0·424	0·0166	0·421	24·80
60	0·0083	0·211	0·0083	0·211	25·00
80	0·0063	0·160	0·0062	0·157	24·60

[1] Quite a contrast is seen in Kennedy's U.S. Pat. 1,260,398, March 26th, 1918, in which bricks are made from silica in particles of substantial size and free from fine silica powder or sand, which is mixed with a binder (generally a small percentage of fireclay).

The grades are expressed thus :—

	Grain Size (diameter)	Number of Grade
Amount which remained on 30 mesh sieve	Over 0·424 m.m. ..	Z_1
Amount which passed 30 mesh sieve and remained on 60 mesh sieve ..	Between 0·424 and 0·211 m.m. ..	Z
Amount which passed 60 mesh sieve and remained on 80 mesh seive ..	Between 0·211 and 0·157 m.m. ..	Y
Amount which passed 80 mesh sieve	Less than 0·157 m.m.	X

The grading by means of sieves is apt to give inaccurate results as pointed out above in carrying out the mechanical tests. The process of grading by water currents is much too long to yield sufficient material to make a series of test bricks even as small as 1" cubes, but with careful sieving the grades may be fairly constant. The dimensions of the grains may not be strictly as given in the table, but the variation should not be appreciable. The finer the grading the more difficult it is to separate by means of sieves, so that the finest grade, No. X is as large as a tenth of a millimeter average—the probability being that the majority of the material passing the 80 mesh is much finer and approximates to the "flour" grade.

The sieving was done as carefully as possible, no more than 5 grammes being on the lawn. The test pieces were made in the ordinary way, dried, and fired together in the furnace with the same precautions observed in the previous preparation of test pieces for crushing tests. The mixtures of the various grades were weighed out as percentages, placed in a clean dry bottle with a tight fitting vulcanite cork and shaken by hand. The shaking should not be too vigorous, or the grading will be altered by the grains being worn down by the attrition caused by the motion of the grains against each other. If a cloudiness appeared in the bottle it proved the shaking to be too vigorous. The material was taken out of the bottle and mixed with a palette knife after the manner of making up a charge for the dry assay of ores. The amount of water added was the least required to mould the brick. Many of the mixtures would not mould at all—breaking as soon as the mould was removed.

A description of the bricks which were made from material of varying grades is interesting.

Description of the test pieces.

No. 1A. This mixture consisted of X grade only, *i.e.*, 100%. The bricks

were easily moulded as the material was comparatively plastic.[1] After being burned a very compact hard brick with well-defined edges was obtained. Scabbing was pronounced, and the colour of the bricks was dark brown. There was no tendency of the brick to become abraded on ordinary handling, *i.e.*, the grains were not easily rubbed away.

No. 1B. This mixture contained 100% Y grade. The bricks made were very fragile and required great care in handling as the slightest touch broke them. They kept their shape in the furnace, but could not be removed without falling to pieces.

No. 1C. This mixture consisted of 100% Z grade, and was practically devoid of plasticity. Using great pressure a few bricks were made which would keep their rigidity and shape for any length of time. The bricks broke in drying without having been touched.

No. 1D. This material consisted of 100% Z1 grade, and was absolutely devoid of any plasticity. Great pressure was required to cause the coarse particles to pack together. When the mould was removed the bricks bulged and fell to pieces.

No. 1E. Contained 90% X grade and 10% Y grade. The bricks were fairly easily made and after burning were quite firm, uniform and compact. The colour of these bricks was paler than that of No. 1A.

No. 1F. Contained 80% X grade and 20% Y grade. The bricks made were similar to No. 1E but were not quite as good.

No. 1G. Contained 60% X grade and 40% Y grade. After burning, these bricks appeared to be slightly darker than No. 1E and No. 1F. The edges were more liable to crumble and the bricks were not so firm and compact.

No. 1H. Contained 50% X grade and 50% Y grade. These bricks required more careful handling than those previously made with X and Y grades. The colour after burning was similar to No. 1G.

No. 1I. Contained 40% X grade and 60% Y grade. The colour of these bricks after burning was lighter than previously made bricks. The bricks were rather fragile.

No. 1J. Contained 20% X grade and 80% Y grade. The bricks were similar to No. 1I but more fragile.

No. 1K. Contained 80% X grade and 20% Z grade. These bricks compared favourable with those made from the X and Y grades. They were fairly easy to mould and when fired had a similar colour but a coarser grain than the former.

No. 1L. Contained 60% X grade and 40% Z grade. With the exception of a coarser appearance after being fired these bricks resembled No. 1I.

No. 1M. Contained 50% X grade and 50% Z grade. These bricks although coarser in appearance compared favourable with those above but were more susceptible to abrasion.

No. 1N. Contained 40% X grade and 60% Z grade. These bricks were lighter in colour and more difficult to handle. The edges were easily broken and grains were easily rubbed from the sides.

No. 1O. Contained 20% X grade and 80% Y grade. These bricks were comparatively difficult to mould and to handle. On burning, a very fragile light brown coloured brick was obtained. The samples either broke or had their edges damaged so much as to be worthless, and when the slightest pressure was put upon them in the testing machine, they broke to pieces.

No. 1P. Contained 90% X grade and 10% Z1 grade. These bricks required care in the preparation but fairly good bricks comparable with those made from mixture No. 1I were obtained.

---

[1] By "plasticity" is meant the ability of the material to retain its shape on removing the mould.

No. 1Q. Contained 80% X grade and 20% Z1 grade. These bricks were fragile and easily broken and spalled.

No. 1R. | No. 1S. | No. 1T. | No. 1U. These bricks (made from the mixtures indicated in the accompanying table) were very difficult to make and even when it was possible to place them in the firing furnace, they fell to pieces at the slightest touch after the burning.

Attempts were made to make bricks using mixtures of varying percentages of Y and Z grades. The mixtures containing more than 60% of Z grade were exceedingly difficult to mould. When the mould was removed it was not possible to lift the brick as the slightest touch caused them to fall to pieces. Those bricks made from Y to Z grades which were fired could not be removed from the furnace except with the care with which they were placed there, and were consequently worthless.[1] Their colour, however, after burning was more or less dark brown. Mixtures of Y and Z grades and of Z and Z1 grades were not proceeded with.

The results of the compression tests, which were carried out in the manner previously indicated, are given in the accompaning table, and which are set out in graphic form (fig. 9). The curves have as ordinates percentage grading, and pressure in lbs. per square inch.

No.	%X	%Y	%Z	%Z1	(i.)	(ii.)	(iii.)	(iv.)	Mean lbs. sq. in. to nearest 5 lbs.
1A	100	—	—	—	325	330	340	335	330
1B	—	100	—	—		worthless			
1C	—	—	100	—		worthless			
1D	—	—	—	100		worthless			
1E	90	10	—	—	280	275	265	270	270
1F	80	20	—	—	235	245	250	235	240
1G	60	40	—	—	170	160	165	160	165
1H	50	50	—	—	135	140	145	140	140
1I	40	60	—	—	90	95	95	90-95	95
1J	20	80	—	—	35	35	45	40	40
1K	80	—	20	—	150	140	145	130	140
1L	60	—	40	—	90	95	95	95	95
1M	50	—	50	—	65	70	—	70	70
1N	40	—	60	—	60	50	55	55	55
1O	20	—	80	—		worthless			
1P	90	—	—	10	80	70	80	70	75
1Q	80	—	—	20	50	60	35	40	45 (?)
1R	60	—	—	40		worthless			
1S	50	—	—	50		worthless			
1T	40	—	—	60		worthless			
1U	20	—	—	80		worthless			

Discussion of the Results. The results of these experiments are exceedingly interesting, and show in a well marked manner the effect of texture or grade of material upon the crushing strength of the brick. The curve of the X and Y grades is remarkably constant, being almost a straight line showing that an addition of Y grade produces a corresponding decrease in the crushing strength. The curves for the X and Z grades and X and Z1 grades

[1] The term "worthless" is restricted to the conditions of these experiments.

are not so regular. There is a sudden and greater decrease in the crushing strength on the addition of the coarser grades, and the coarser the grade size of the particles added the greater the decrease in crushing strength. After the first addition of the coarser grades the loss in strength is fairly regular. Some idea of the effect of the increase in size of the particles added to the finest grade material, may be obtained by comparing the crushing strength of the mix-

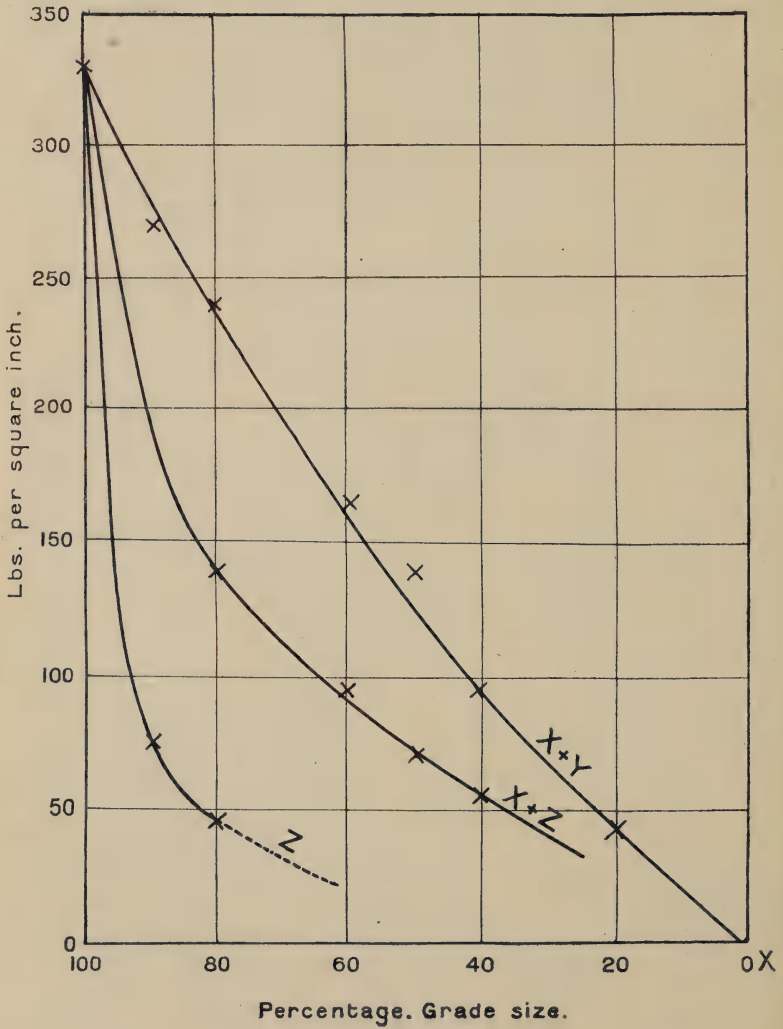


Fig. 9.

ERRATA: Curve Z should read $X + Z_1$

tures with the same percentage of X with the grades Y and Z, thus :

80% X : 20% Y crushing strength = 240 lbs. per sq. inch
80% X : 20% Z ,, ,, = 140 ,, ,, ,,
80% X : 20% Z_1 ,, ,, = 40 ,, ,, ,,

It is at once seen that an increase in the size of the grains added causes a lowering in the crushing strength of the brick which is approximately corresponding to the increased size. It is pointed out that those mixtures which contained no material of No. X grade were either incapable of being made into bricks, or the bricks which were made were worthless. These experiments prove that the finer the grade of the raw material used the stronger the brick, and that some material of the "flour" grade is essential in the preparation of bricks.

Va. THE DRYING OR AIR SHRINKAGE OF THE MATERIALS.

The great difficulty in these experiments was the care required to ensure even and complete drying of the test piece, also in the handling, marking, and measuring owing to the great frailness of the unfired brick. The test piece after moulding was accurately marked by means of a pair of dividers fitted with a screw adjustment. The ends of the dividers were filed true and chisel-pointed. It was not possible to draw any straight lines on the face of the brick, so two fine marks were made at known distances apart by means of the dividers. The inner distances between the marks were taken as the true distances. On each brick two pairs of marks were made.

The bricks (3 of each material) were placed upon a raised perforated board slightly and evenly oiled, and allowed to dry out of contact of any draughts in a fume cupboard. In this way the brick was dried evenly throughout its whole mass ; the time allowed was 2 days (48 hours). The bricks were then placed in an air-oven and heated at 70°C. for 4–5 hours and finally by slowly increasing the temperature at 110° for at least 2 hours. The bricks were cooled in the oven and then in a large desiccator and measured rapidly to prevent any possible absorption of atmosphere moisture. The distance between the marks was measured with a sliding calliper rule fitted with vernier scale. Readings up to three places of decimals were quite trustworthy, but the fourth place was not relied upon except to aid the third.

The results were as follows :—

Sample No.	Length when wet		Length when dry		Mean difference %		Shrinkage mean %
1. A.	2·500	2·500	2·469	2·469	·031	1·2	—
B.	2·500	2·500	2·500	2·501	nil	—	—
C.	2·000	2·000	1·984	broke	·016	1·30	1·28
2. A.	2·500	2·500	2·494	2·500	·006	0·24	—
B.	2·500	2·500	2·484	2·486	·015	0·60	—
C.	2·000	2·000	1·984	1·985	·016	0·80	0·70
3. A.	2·000	2·000	1·969	1·969	·031	1·65	—
B.	2·000	2·000	1·978	1·969	·031	1·65	—
C.	2·000	2·000	1·969	1·969	·031	1·65	1·65
4. A.	2·000	2·000	1·983	broke	·017	0·85	—
B.	2·000	2·000	2·000	1·984	·016	0·80	—
C.	2·000	2·000	1·970	1·969	·030	1·50	1·05
5. A.	2·000	2·000	1·984	1·984	·016	0·80	—
B.	2·000	2·000	1·984	1·984	·016	0·80	—
C.	2·000	2·000	1·984	1·984	·016	0·80	0·80
6. A.	2·000	2·000	1·991	1·989	·010	0·50	—
B.	2·000	2·000	1·983	1·984	·016	0·80	—
C.	2·000	2·000	1·984	1·984	·016	0·80	0·70
7. A.	2·000	2·000	1·985	1·985	·015	0·75	—
B.	2·000	2·000	1·984	1·984	·016	0·80	—
C.	2·000	2·000	1·984	1·984	·016	0·80	0·80
8. A.	2·000	2·000	1·992	1·990	·009	0·450	—
B.	2·000	2·000	1·984	1·988	·014	0·700	—
C.	2·000	2·000	1·986	1·986	·014	0·700	0·62
9. A.	2·000	2·000	2·000	2·000	nil	—	—
B.	2·000	2·000	1·988	1·990	·011	0·55	—
C.	2·000	2·000	1·984	1·984	·016	0·80	0·67
10. A.	2·000	2·000	1·984	1·984	·016	0·80	—
B.	2·000	2·000	1·984	1·984	·016	0·80	—
C.	2·000	2·000	1·984	1·984	·016	0·80	0·80

The values are calculated and expressed as a percentage of the length of the wet piece. The shrinkage shown is small—the largest value obtained 1·65 for sample No. 3 means a linear shrinkage of 0·1485 on a 9 inch brick, *i.e.*, just less than 5/32nd inches. The largest value for silica rock material proper was given by sample No. 1, but the average value for the rock material is about 0·8% giving for a 9 inch brick 0·072, *i.e.*, less than $\frac{1}{16}''$ ($\frac{1}{16}''=0{\cdot}0625''$).

The drying shrinkage depended to a large extent upon the texture or grain size of the material and upon the uniformity of texture. If the grains were of such sizes that they fitted closely together, the pore space between the grains was small and it follows that the amount of shrinkage must be small as there is little room available. This is shown by comparing sample No. 4 and sample No. 9. The mechanical analyses are:—

	No. 4.	No. 9.
Grade 1 ..	18·5	23·75
Grade 2 ..	27·9	41·75
Grade 3 ..	31·0	25·9
Grade 4 ..	22·6	8·6

The grading of sample No. 9 is such that the pore space is less than that of sample No. 4. Consequently the shrinkage of sample No. 9 is lower than that of sample No. 4—there is a difference of $1{\cdot}05-0{\cdot}67=0{\cdot}38$[1]. The connection between drying shrinkage and chemical composition is not definite. There is a tendency for the materials possessing comparatively high shrinkage results to be comparatively rich in alumina or in oxide of iron.

B. The changes in length on firing to comparatively low temperatures. Some experiments were conducted on the unfired test pieces and the change in length on slow heating to certain temperatures was determined. The bricks were carefully placed as near as possible to each other in a large muffle furnace heated by the town gas. The rate of heating was controlled by pyrometers. The rate of increase of temperature has to be slow and regular in order not to disturb the cohesion between the grains of quartz. Rapid and irregular heating causes the bricks to expand or contract irregularly setting up spalling effects. The rate of increase of temperature was kept as near as possible 100°C. per hour and above 900°C. the rate was decreased to 50°C. per hour. As soon as the desired temperature was reached the bricks were given time to attain the same temperature throughout. (15 mins. were sufficient, because the rate of heating was slow and regular, and the size of the bricks was small). The damper of the furnace was then closed and the gas supply turned off at the main in order that the cooling should be as regular as possible from front to rear of the furnace. Even with these precautions an equal temperature throughout the whole length of the furnace was probably not maintained within a limit of 5°–10°C. from the front wall to the back of the furnace. Minor fluctuations are impossible to prevent—the town supply of gas is erratic and its pressure and quality does not remain absolutely constant. The furnace was allowed to cool down in its own time, and when cold the test pieces were withdrawn and measured as quickly as possible. The measurement of the distances between the marks was conducted in the same manner as that used in the determination of the drying and shrinkage. The differences in length are entered as percentages of the original length. Before being measured the bricks were minutely examined and if any small cracks were discovered the test piece was discarded.

The change in length on firing to 1,000°*C.* The test pieces marked A were fired together to 1,000°C. in the manner described above. The following results were obtained :—

[1] No. 4 is found to be more evenly graded than No. 9 and is also more fine grained. It may be stated in general that increasing fineness means increasing pore space.

Sample No.	Length when wet		Length when burned to 1,000°C.		Mean difference	Mean % Shrinkage on wet piece	% Shrinkage due to fire alone
Col. 1.	2	3	4	5	6	7	8
1. A.	2·500	2·500	cracked	2·463	·037	1·480	0·20
2. A.	2·500	2·500	2·489	2·491	0·010	0·400	0·16
3. A.	2·000	2·000	1·961	1·961	0·039	1·950	0·30
4. A.	2·000	2·000	1·977	cracked	0·023	1·150	0·10
5. A.	2·000	2·000	1·972	1·971	0·029	1·450	0·65
6. A.	2·000	2·000	broken	broken	—	—	—
7. A.	2·000	2·000	broken	broken	—	—	—
8. A.	2·000	2·000	1·978	1·978	0·022	1·100	0·48
9. A.	2·000	2·000	1·980	1·981	0·021	1·050	0·38
10. A.	2·000	2·000	cracked	1·979	0·021	1·050	0·25

The above results are interesting in so far as they show some small shrinkage due to burning. The temperature of 1,000°C. is low and the time of burning much too short to allow any of the forms of crystalline silica (other than quartz) to be formed to any appreciable extent. In this burning it is probable that the only change is the complete expulsion of all water which escaped evaporation in the drying at 110°C. and the burning off of carbonaceous matter.

Specimen No. 2a showed a very low drying shrinkage and was not considered in the mean result, but the shrinkage due to fire alone does not show such a very low value. The original brick was probably imperfectly made, the material not mixed properly, or a lack of uniformity in the texture of the interior of the test piece. The higher values for "fire shrinkage"[1] are on the whole amongst the sands, the highest value 0·48% of No. 8a, being on a 9-inch brick, 0·0432 which is less than $\frac{1}{16}$", *i.e.*, 0·0625". The average shrinkage on burning to 1,000·C. for the silica rocks is about 0·2% giving on a 9-inch brick 0·0180—a little more than $\frac{1}{64}$" or 0·0156.

On the whole the bricks are still fragile and require careful handling. They all had a more or less pronounced pink colour instead of the brown before burning. The colour of the brown limonite patches of the unfired brick were unaltered to any extent, but no fresh patches developed. It is an interesting point that the bricks with the least shrinkage were the most fragile and required most care in handling. Bricks made from the rock material showed least shrinkage and the largest number of breakages.

The change in length on firing to 1,100°C. The test pieces marked B were fired up together to 1,100°C. in the manner described above.

The following results were obtained :—

[1] Col. 8 is obtained by the difference between Col. 7 and the mean % air-shrinkage, *i.e.*, it gives the shrinkage due to fire alone.

No. of Sample	Length when wet		Length when burned to 1,100°C.		Mean Difference	Mean% on length of wet brick	Mean% air shrinkage	%shrinkage due to fire alone[1]
Col. 1.	2	3	4	5	6	7	8	9
1. B.	2·500	2·500	2·480	2·478	0·021	0·84	1·28	–0·44
2. B.	2·500	2·500	2·495	2·497	0·004	0·16	0·70	–0·54
3. B.	2·000	2·000	1·981	1·981	0·019	0·95	1·65	–0·70
4. B.	2·000	2·000	1·985	1·981	0·017	0·85	1·05	–0·20
5. B.	2·000	2·000	1,983	1·983	0·017	0·85	0·80	0·05
6. B.	2·000	2·000	1·961	1·964	0·26	1·30	0·70	0·60
7. B.	2·000	2·000	broke	broke	—	—	0·80	—
8. B.	2·000	2·000	1·985	1·990	0·013	0·65	0·62	0·03
9. B.	2·000	2·000	1·991	1·992	0·009	0·45	0·67	0·22
10. B.	2·000	2·000	1·985	1·985	0·015	0·75	0·80	0·05

The minus results in the last column show that the shrinkage has been passed, and that the quartz is slowly beginning to change into its other forms. The brick has commenced to expand and its length is increasing, so that the minus values are contraction due to shrinkage and become plus values due to elongation or expansion. The plus results in the last column merely show that the expansion commenced has not been sufficient to compensate for the contraction due to shrinkage. It must be remembered that the bricks were not allowed to remain at 1,100°C. for any length of time ; had they been allowed to, the probability is that the elongation would be much larger. The time is not sufficiently long to allow of appreciable transformation of the quartz into its other forms, tridymite or cristobalite.

On the whole the effect of the higher temperature is to make the bricks less difficult to handle. The colour was a slightly darker pink and the limonite coloured spots were although the same in number much darker—in a few cases being quite black. The bricks were not so fragile, but yet would not stand ordinary handling; breakages were much less.

The change in length on firing to 1,200°*C.* The test pieces marked C were fired together to 1,200·C. in the manner already indicated, and the following results were obtained :—

No. of Sample	Length when wet		Length burned to 1,200°C.		Mean diff.	%diff. on length of wet piece	Mean% air shrinkage	Diff. col. 7 and col. 8
1. C.	2·000	2·000	1·994	1·994	0·006	0·30	1·28	–0·98
2. C.	2·000	2·000	2·001	2·002	–0·0015	–·075	0·700	– ·775
3. C.	2·000	2·000	1·992	1·991	0·009	0·45	1·65	–1·20
4. C.	2·000	2·000	1·989	1·990	0·011	0·55	1·05	–0·50
5. C.	2·000	2·000	1·983	1·983	0·017	0·85	0·80	0·05
6. C.	2·000	2·000	1·982	1·982	0·018	0·90	0·70	0·20
7. C.	2·000	2·000	1·990	1·988	0·011	0·55	0·80	–0·25
8. C.	2·000	2·000	1·985	1·987	0·014	0·70	0·62	0·08
9. C.	2·000	2·000	1·991	1·993	0·008	0·40	0·67	–0·27
10. C.	2·000	2·000	1·995	1·998	0·004	0·20	0·28	–0·60

[1] The last column is obtained by the difference between the numbers of column 7 and the mean result in percentages of the air shrinkage given in Col. 8.

The minus differences in this table between the change in length due to the burning and due to the drying are larger, *i.e.*, the expansion is increasing, so much so that in No. 2C the length of the brick is now 0·0015 greater than its length when wet. The samples which still have a plus difference in the last column are all hearth sands which contain more clayey material than the ground silica rock. (This material has a tendency to decrease the expansion or rather to contract itself. No. 5 and No. 8 show the greatest average fire and air-shrinkage). The test pieces on the whole are much stronger, darker pink in colour with a tendency to a brownish colour. The patches were much darker in colour and seem to suggest the formation of the black magnetic oxide of Iron (Fe_3O_4) the highest oxide.[1] The sand grains at the sides were not so liable to rub away on handling, the edges are much sharper and well defined.

General discussion of the Results. In the tables some of the results seem erratic, but on the whole there is a fair similarity. The results of the tests on the rock materials agree amongst themselves, but differ to a noticeable extent from some of the hearth sands.

It is only to be expected that a certain amount of fire shrinkage takes place. This is due to the tendency of the particles to flux and draw close together. Once this has happened, the expansion, due to the slow changing of the quartz into its modifications with lower specific gravity, begins to be apparent. It is seen from the results of these experiments that this shrinkage does take place but may be said to be completed at about 1,000°C. to 1,100°C. From then the expansion becomes the greater the higher the temperature and the longer the time of burning.[2]

These conclusions are in close agreement with the work of Bleininger & Ross,[3] and of Bigot.[4] The latter asserts that "Siliceous rocks begin at 1,200°C. to undergo an expansion which increases by degrees up to 1,710°C. During this expansion the nature of the silica is modified." The former state "that at 1,100–1,300°C. siliceous rock material undergoes expansion, and at 1,300°C. 5–10% of the quartz has been converted into cristobalite."

It is noted that samples No. 5, 6 and 8 give plus values for the fire shrinkage measured at 1,100°C. and 1,200°C. thus differing from the minus values of the other materials. Sample No. 5 and sample No. 8 are both hearth sands, and on referring to the chemical

[1] The brown and black patches on the test pieces are due to the iron compounds present. The black spots or "scabs" given on prolonged heating in an oxidising atmosphere may be composed of the magnetic oxide of iron and (or) ferrous-alumino-silicate formed from pyrite.

It should be noted that at the higher temperatures of 1,100°C. and 1,200, it is more difficult to keep a constant temperature. Differences in temperature from front to rear of the mass of bricks are liable to be pronounced unless great care is used and frequent temperature readings taken. Cold air should be kept out of the furnace, as the effects are not only to break the bricks but to upset the gradual rise or fall in temperature.

[2] See Section VI., p. 385, on the effect of reburning.

[3] *Trans. Amer. Cer. Soc.*, 1916, p. 519.

[4] TRANS. **17**, 263, 1918.

analyses[1] and the mechanical analyses[2] it is observed that they contain a comparatively large amount of the clayey substance shown by the high percentage of alumina, and the relatively large amount of material of fine grade. The presence of such a comparatively large amount of clayey substance accounts for the values being plus rather than minus. There is a large shrinkage value due to this "clayey" material. The values would probably become minus values had a longer time been given the bricks at these temperatures. They show on the whole an expansion, as the differences of length in percentages between the mean air shrinkage and the difference in length on burning show a decreasing value from the A to the C sample; *e.g.*, No. 5 the difference decreased from 0·65 on burning to 1,000°C. to 0·05 on burning at 1,100°C. and 1,200°C.

This explanation does not apply to sample No. 6—which is a rock material and not a sand. The chemical analysis[3] shows the rock to have the highest percentage (99·14) of silica. The mechanical analysis[4] shows a preponderance of material of the medium grade with a small amount of "flour." Microscopical analysis[5] shows that this material has less chert than the average amount present in the rock materials. Probably the factors causing the plus value are not as in sample No. 5 and sample No. 8, a large shrinkage value, but a slower rate of conversion of the quartz and hence a slower rate of expansion. The slower rate of conversion is probably due to any or all of the following causes:—(i). The comparative absence of fluxing impurities. (ii.). The relative small amount of the finer grade material. (iii.). The small amount of chert present.[6] That there is an expansion is shown by the decreasing values from 0·6 in No. 6B to 0·2 in No. 6 C.

It is noted that breakages (including bricks with small cracks) were more numerous in bricks made from the silica rock materials than those made from the silica sands. The latter possess a comparatively large amount of "clayey" material with the result that the sands have a preponderance of fine grade material. The "clayey" material is so fine grained that it forms a matrix and cements the quartz grains together.

VI. THE EFFECT OF REBURNING THE BRICKS.

Considerable work has been done upon the changes taking

[1] p. 361.
[2] p. 368.
[3] see p. 361.
[4] see p. 368.
[5] see p. 363.
[6] Mellor, Moore & Campbell, in "Studies on Flint and Quartz" in TRANS. **15**, 1916, state that the rates of transformation of quartz and of crypto-crystalline silica into the forms with lower specific gravity are different. With quartz the change is relatively much slower, being only one-third of the rate of that of flint. Curves are shown pointing out this difference with rate of conversion. The authors also state that there is probably no difference between the lower forms β flint and β quartz being virtually the same substance.

place in the silica of silica bricks during usage. The works of Le Châtelier, Scott, Bigot, McDowell, Fenner, and Graham are worthy of notice.

Le Châtelier[1] affirms the impossibility of obtaining complete transformation of the quartz into its forms with lower specific gravity in the first burning. He states that the complete transformation required weeks in a steel furnace where the temperature is much higher than that in the firing kiln.

In an examination of a silica brick taken from the roof of a basic open hearth furnace after 135 changes Graham[2] found that in the end of the brick remote from the action of the flames only the siliceous groundmass had been transformed—the quartz being practically unaltered.

These conclusions are very strongly supported by McDowell[3] and by Scott[4]. The latter failed to find anything like complete transformation in a number of British silica bricks which were examined. That the rate of transformation of the quartz is influenced by the non-siliceous matter present in the brick is well shown by Scott who investigated the effect of various binding materials on practically pure quartz. His conclusions point out that the factors which influence the conversion from high to lower specific gravity forms are (1) nature and amount of non-siliceous matter present, (2) grain size of the quartz, (3) temperature and duration of firing.

In order to study the transformation of the quartz of the raw material itself and to eliminate the influence of any added binding agent test pieces were made from sample No. 1.

The test pieces were made a cube on 1″ dimension, dried and burned at a temperature of 1,350–1,400°C. in the manner previously indicated. The maximum temperature was reached in about twelve hours and maintained there for ten hours after which time the furnace was allowed to cool slowly. A sufficient number of pieces for testing were taken out, and the remainder heated up again carefully and maintained at 1,350–1,400°C. for ten hours. This was repeated until the last batch was burned five times at the same temperature but for twenty hours at the fifth burning.

The raw material from which these test pieces were made had the following grading :—

Sample No. 1A	Grade 1	..	14·8%
	Grade 2	..	41·0%
	Grade 3	..	33·8%
	Grade 4	..	10·4% (by difference)

The appearance of the test pieces was as follows :—

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[1] Trans., **17**, 10, 1918.
[2] Trans., **18**, 399, 1919.
[3] *Trans. Amer. Inst. Min., Eng.*, **54**, 999, 1916.
[4] Trans., **17**, 137, 1918.

(1). After the first burning—light brown in colour, very friable but withstood handling fairly well.
(2). After second burning—slightly darker in colour, not so friable and less difficult to handle.
(3). After third burning—much stronger brick, darker in colour and compact.
(4). After fourth burning—slightly darker in colour.
(5). After fifth burning—very similar to the bricks after the fourth burning.

The texture of each batch was uniform. Test pieces from each batch were tested for compression, porosity and specific gravity. The compression tests were carried out in the manner indicated above; at least four test results each showing the typical pyramidal fracture were desirable and the mean taken. The method of making the porosity and specific gravity tests is that indicated by the "Report of the Committee for the Standardisation of Tests for Refractory Materials."[1] The specific gravity test results were checked by the pyrometer method.[2] The results of the tests are as follows:—

No. of burnings	Apparent specific grav.	True specific grav.	Porosity	Compression str. to the nearest 5 lbs. per sq. inch
1	1·401	2·489	43·72	145
2	1·404	2·479	43·41	185
3	1·343	2·477	45·80	200
4	1·346	2·463	44·85	205
5	1·323	2·433	45·64	210

The results of the change in specific gravity (true) and in the crushing strength on reburning are indicated graphically. (fig. 10).

It is noted that the greatest change in the specific gravity after the initial burning takes place at the fifth burning, but the greatest change in compression strength is at the second burning. After the fourth burning the change in compression strength is practically negligible.

In order to study the changes in specific gravity on repeated burnings and also the effect of a variation in the grade of the raw material similar experiments were carried out. A fresh batch of test pieces were made from the No. 1 Sample. On elutriation this sample had the following grading:—

Sample No. 1B

Grade 1	..	20·2%
Grade 2	..	49·6%
Grade 3	..	22·4%
Grade 4	..	7·8% (By difference)

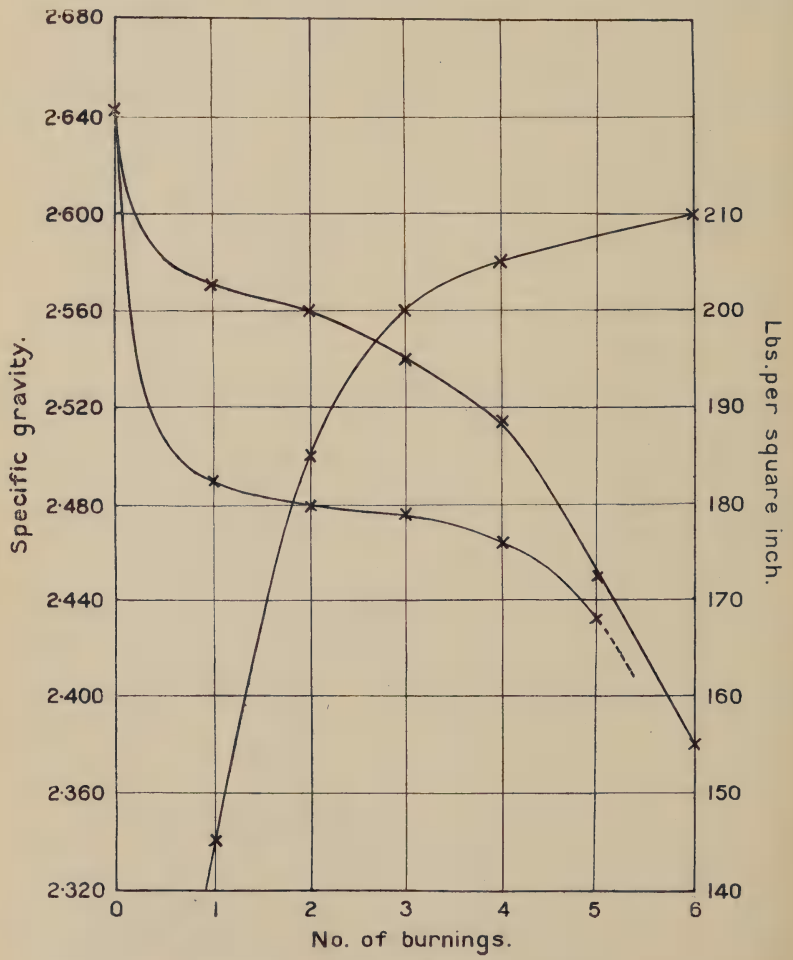
The bricks were burned at 1,350°–1,400°C. reached in about twelve hours, and maintained there for twelve hours. The burnings

[1] Trans., **17**, 314, 1918.
[2] Determination of the spec. grav. by the pyrometer method is quicker and more liable to give accurate results than by the immersion method owing to the great tendency of the grains to be easily rubbed away in these test pieces. The immersion method has the advantage of giving the porosity (water absorption) and the apparent specific using the same data.

were repeated until the last batch was burned six times. The specific gravity determinations were made on the unfired and fired material by the pyrometer method. The results of the tests are as follows:—

No. of burnings ..	0	1	2	3	4	5	6
Spec. grav. ..	2·644	2·571	2·560	2·540	2·514	2·448	2·380

The results which are indicated graphically are exceedingly interesting. There is seen to be an increase in the strength of the brick especially after the second burning. After three burnings



Fig, 10.

the brick has practically reached its maximum strength. This increase in strength probably depends more upon the length of the time of burning during which the fluxes or impurities present bind the grains more closely together so making a compact brick, rather than upon the amount of quartz or its forms with lower specific gravity which is present. It is seen above[1] in the results of the compression tests that the material with this grading gave a compression strength after continuous burning for seventy-two hours of 210 lbs. per square inch.

Both series of experiments show conclusively that on each repeated burning more of the quartz is changed into its modifications with lower specific gravity. The greatest change in specific gravity occurs at the first burning, but the change is not complete. The change proceeds and it is not until the sixth burning that anything like a complete change has taken place. It is probable that had the temperature of burning been 1,500°C. in these experiments the differences between successive burnings would have reached a minimum after the third or fourth burning.

That the texture plays a very important part in the change of the quartz to its forms with lower specific gravity, is well seen by a comparison of the two sets of results of the experiments on the same material. Sample No. 1A was a finer grade material than Sample No. 1B. A comparison of the tables given shows that although Sample No. 1B was fired consecutively for twelve hours and Sample No. 1A for ten hours, yet the specific gravity had changed on the first burning to 2·571 in the former material, and to 2·479 in the latter. The change in specific gravity of the finer grade material was greater after one burning only than the change in the coarser material after four burnings. These results show that the finer the grade of the raw material the greater the speed of conversion of the quartz to the modifications of lower specific gravity. In order to obtain the maximum change in the initial burning in the kiln the material must be as fine grade as possible.

The results of the porosity experiment are erratic. An increase in porosity is noticed on the whole, but the results are not conclusive.

Scott[2] states that the conversion of the quartz in silica bricks is due to the solution of the quartz by the silicates formed by the impurities and added binding material and the subsequent precipitation of the dissolved silica as tridymite or cristobalite (the forms of quartz with low specific gravity) depending upon temperature, etc. So that for standard conditions of temperature and grain size the conversion will depend upon the solubility of the

[1] Vide p. 387.

Note.—It was not possible to examine microscopically the changes taking place in the brick on repeated burnings owing to the extreme difficulty of preparing thin sections due to the friable nature of the test pieces.

[2] Trans., **18**, 481, 1914.

quartz in the molten silicates and the viscosity of the latter.

It is noticed that there is a decrease in the slope of the specific gravity curve of sample No. 1A after the first to the fourth burnings, *i.e.*, the change in specific gravity is very small after the first burning until the fifth burning (which was prolonged)[1]. After the fourth burning the curve again takes a steep slope. The curve for sample No. 1B has a regular slope after the first burning. After the fourth burning the slope of the curve is as steep as the corresponding part of the curve of sample No. 1A. It is tentatively suggested that after the first burning the influence of texture is not so pronounced, as the smaller grains have been converted without solution by the fluxing impurities, *i.e.*, by their small size the grains have been converted "in situ." After the first burning in subsequent burnings solution plays an important part.

VII. GENERAL SUMMARY AND CONCLUSION.

The work done is regarded as a preliminary investigation rendered necessary by the small amount of detailed information which has been published on the materials used in South Wales for the manufacture of silica bricks. A great deal yet remains to be investigated. There is no question of the suitability of the materials used in this work; the bricks made from these rocks are of wide renown, and are in great demand both at home and abroad. "Refractoriness" has been the keynote of the industry. The importance of the refractoriness of the materials is not denied, but it is asserted that the grading of the materials has not received the amount of attention which it deserves. The connection between texture and the resultant property of the brick is intimate. It is upon correct grading of the raw materials and its coincident property of texture that other properties including refractoriness of the manufactured brick depend.

The importance of texture and correct grading of the materials is emphasised in this work. Texture has been shown to affect:— (1). The drying shrinkage. (2). The fire shrinkage. (3). Rate of conversion of quartz into the forms with lower specific gravity. (4). Crushing strength.

1. *The largest values for the drying shrinkage are given by those materials with the most space between the grains.*

2. Abnormal values for the "fire shrinkage" are due to the effect of texture. It is noted that the large values in two of the materials are due to the large amount of clayey materials they contained with a consequent large amount of material of fine grade. The material whose high value is due to the slow rate of conversion of the quartz it contains had a comparatively small amount of material of the finest sized grade.

[1] For purposes of comparison the fifth burning of twenty hours may without serious error, be taken as two burnings of ten hours each duration.

The largest values for fire shrinkage are given by those bricks which possess the closest texture and whose chemical composition reveals the presence of a comparatively large amount of clayey substance. With a low clay-content, the finer the texture the less the shrinkage.

3. The experiments on reburning point out the influence of texture on the speed of the conversion of quartz. Both series of experiments were conducted under identical conditions. Although heated repeatedly for periods of twelve hours the change in specific gravity of the coarser material was slower than that of the material of finer grade which was burned for periods of ten hours. *Hence the finer grained the brick the greater is the speed of the conversion of the quartz into its modifications of lower specific gravity.*

4. The bricks[1] which gave the highest values for the crushing strength were made from fine grade material. The lowest results were obtained from those materials which contained a comparatively large amount of material of coarser grade.

The connection between crushing strength and texture is shown more conclusively in Section Va. It is seen that some of the finest grade material was necessary to produce bricks with good compression strength, and that the smaller the size of the grains the stronger was the brick. Bricks which were made from material not containing any of the finest grade were exceedingly difficult to mould and to handle—they were practically devoid of plasticity. Within the conditions of the experiment the bricks were worthless, possessing very little or no resistance to crushing strain. Hence the finer the texture of the raw material the stronger the brick.

Sufficient evidence has, therefore, been obtained to prove the close connection between texture and the resultant properties of the bricks. A knowledge of the grade of the material used and hence of the texture of the manufactured brick is necessary for the correct specification of bricks needed for any particular use. By attention to the mechanical analysis the risk of failure is minimised and the longest service possible obtained from the bricks. In any one furnace the bricks used should not be identical in texture. The texture should be varied to meet the conditions prevailing at any particular part of the furnace. The days of the "Trial by error" method and of the so-called "experience" have to give place to scientific reasoning if industry is to be carried out on a sound economic basis.

In conclusion, the author has to express his great indebtedness to Professor A. A. Read, D.Met. for the sympathetic interest and advice which he has shown in the work. The author also desires to thank Principal J. Dobbie, for permission to use the Riehlé Testing Machine at the School of Mines, Crumlin, and for his assistance in carrying out the crushing tests; and to thank Professor

[1] The bricks made from these materials gave high values for drying and fire shrinkage.

A. H. Cox, D.Sc., for his assistance in the preparation of the paper.

APPENDIX No. 1.

The Preparation of Test Pieces from the Raw Material.

Contrary to commercial practice the test pieces were made without the addition of any binding material. The addition of the bond introduces a new unknown factor. These investigations are on the raw material rather than upon the finished product, and hence it is obviously desirable to eliminate the effect of an unknown factor upon the properties of the materials. As a result the preparation of the test pieces was a difficult matter requiring care, and patience in the handling of the bricks before they were fired. Comparatively little detailed work has been published regarding the effect of the bond upon the properties of silica bricks. The work of Scott[1] on the "Factors influencing the Properties of Silica Bricks" is important, and has done much to solve this problem of the binding material.

The material was crushed by vertical action of the pestle in the mortar and passed through the I.M.M. standard 30 mesh sieve. A sample of each material was elutriated in order to obtain a check on the results of the experiments.

The material was well mixed with a quantity of water just sufficient to enable the test piece to retain its shape when the mould was removed.

The mould was made of well planed wood in the shape and dimensions shown :—

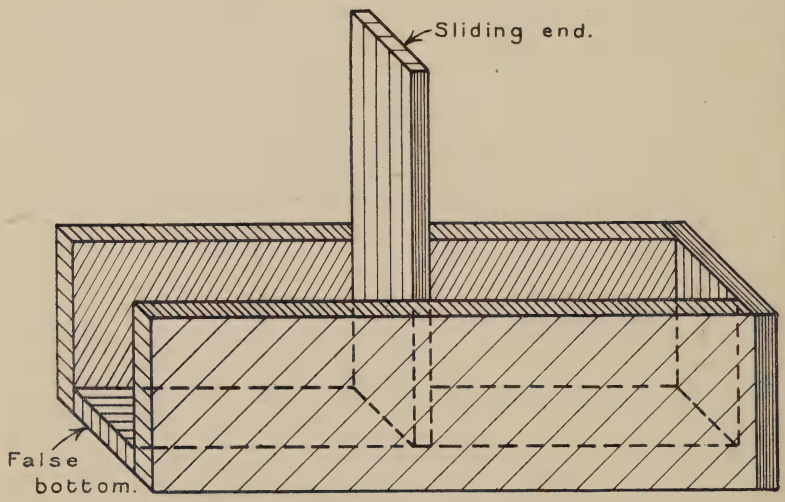


Diagram of wooden mould.

Fig. 11.

The mould was slightly and evenly coated with light lubricating oil in which about 10% of vaseline had been dissolved by slight heating. This oil leaves no residue on ignition. By thus coating the mould with oil, the brick is not damaged when the former is removed. The shape of the mould is such that the sides and end can be withdrawn leaving the moulded brick standing on the false bottom.

[1] Trans., **18**, 481, 1918.

The material was placed in the mould and to ensure uniformity of texture of the brick, it was well stabbed by means of a palette knife. The sides were gripped tightly and a piece of planed wood was held firmly on the top. The sliding end was then pushed slowly and evenly inwards so that pressure was exerted on all sides of the mould at the same time. When the end could be pushed inwards no more, the top was moved and the surface smoothed with the palette knife. The sides were gently tapped to loosen the brick from the sides and bottom. The sides were pulled or lifted carefully and the brick was left on the false bottom. The brick was then placed on a large board numbered and allowed to dry. By suitable positions of the moveable end any length of test piece can be made.

XXIII.—The Thermal Conductivity of Refractory Materials at High Temperatures.

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Communication from the Clay and Pottery Laboratory, Stoke-on-Trent.—No. 102.

By A. T. Green.

THE problem of fuel economy in many of its varied aspects has given considerable impetus to the study of the thermal criteria of refractories. The heating efficiency of much high temperature work cannot be computed without those quantitative data which measure the fundamental thermal properties of clay products. Then, again, improvement in the technique of many industries has made it apparent that refractories must be roughly divided into two groups—*i.e.*, conductors and insulators. The gas-retort or the coke-oven wall is the more efficient the more quickly the heat is transferred through it and the greater the ease with which the desired temperature is attained on the carbonizing face; while the more nearly the blast-furnace lining approaches a perfect thermal insulator the greater is the heat conservation during the smelting of iron. Clearly, then, thermal conductivity should exert considerable influence in the selection of refractories; its importance being sufficient to merit the consideration of those who scheme the essential specifications of such materials.

During the last ten years or so several investigations of the thermal conductivity of refractories have been attempted. A variety of methods has been adopted; but the results cannot be considered concordant. The reported values of the co-efficient of thermal conductivity seem to depend on the nature of the adopted method, and, consequently, a discussion of this previous work may form a criticism of the present paper.

Review of Previous Work, Together with the Principles of Thermal Conductivity.

A.—Methods depending on the use of a calorimeter.—Consider a uniform plate with parallel walls such that one face is maintained at a temperature θ_1, and the other face at a temperature θ_2. Suppose that a quantity of heat Q, passing through the plate in a time t, is necessary to maintain the two faces at the above temperatures. Then, if the thickness of the plate is x and its area is A,

$$Q = \frac{K\ (\theta_1 - \theta_2)\ At}{x} \qquad (1)$$

where K is an assumed constant, depending on the nature of the

substance, and is known as the co-efficient of thermal conductivity, or just the "thermal conductivity" of the material. In C.G.S. units it is the number of calories transmitted from one face of a cube of edge 1 cm. to the opposite face in 1 second, when the two faces are maintained at temperatures differing by 1° C. Formula 1 has been used as the basis of almost all the work on the conductivity of refractories. Its use entails a measurement of $\frac{Q}{t}$ the heat term, which may be obtained either calorimetrically or electrically. Wologdine's (1) work was the forerunner of the "calorimetric" investigations. The object of this work was to seek a relationship between thermal conductivity and temperature, porosity, permeability to gases, and temperature of firing for a large number of French refractory products. A circular disc, 5 cm. in thickness, with bevelled edges, was used as the specimen piece. This test shape formed the top of a gas-fired muffle. Two platinum—platinum-rhodium thermo-couples were placed at distances of 5 mm. from each face, and these served to indicate the temperature of the faces themselves. Guided by experiment, the investigator assumed a linear gradient of temperature through the brick, and, by subsequent extrapolation, these two face temperatures were obtained. The factor $\frac{Q}{t}$ was measured by means of a water flow calorimeter resting on the cooler surface of the specimen. This measurement is open to much criticism. It is obvious that the cool surface of the calorimeter distorted the heat flow through the specimen from its normal direction, and since no "guard ring" was used with the object of preventing this, a serious error was introduced into the experiment. The temperature measurement can be criticised by reason of the fact that the thermal conductivity increases with temperature, and the assumption of a linear gradient of temperature cannot be maintained. All the test-pieces were specially made. This, in itself, forms an objection, since it is of particular consequence to the industrial value of the results that ordinary commercial bricks of standard size and shape should be used. A detailed criticism of the errors in Wologdine's work can be found in papers by Goerens (2), Heyn, Bauer, and Wetzel(3), and in an excellent review of the principles relating to the methods of determining the thermal conductivity of refractories by Rosin (4).

Goerens (5), seeking improvements in the technique of Wologdine's method, elaborated a "guard ring" for the flow calorimeter in order to maintain a parallel heat flow. This"guard ring" consisted of an outer jacket through which water was allowed to flow continuously. The jacket rested along the whole length of the material. The heating was obtained by a nickel-chrome resistance wire wound round a fireclay plate, and the temperature gradient determined by means of a series of couples embedded in

the material and runningparallel to the hot face. Commercial bricks were used as specimens.

Dougill, Hodsman, and Cobb (6) also used a method very similar to that of Wologdine. They jacketted the calorimeter with a second calorimeter at the same temperature. One critic (7) has already suggested that since the two calorimeters were in metallic connection the existence of even a slight gradient across the metal base would adversely affect the results. The heat term $\frac{Q}{t}$ was measured by the rate of evaporation of water from the calorimeter. As in Goerens' work, commercial bricks were used. The higher temperatures (over 900°C.) were determined by means of a Holborn-Kurlbaum optical pyrometer. Considering the accuracy of the temperature measurements necessary for successful results, and the difficulties attending the use of optical pyrometers when correct absolute temperatures are required, such data must, at least, be doubted.

Boyd Dudley (8), using American standard-sized, commercial fireclay, silica, and magnesite bricks, followed the recognized principles of the calorimetric method, a flow calorimeter with a "guard ring" being used to measure the heat term. A wall of similar material forming part of a coke-fired furnace was used as the test material. The combustion in the chamber was carefully regulated with the object of obtaining an even temperature. This does not appear to have been an easy matter, although continued experience helped the investigator considerably. Thermo-couples placed in holes bored from the cold face towards the hot face to within varying distances of the hot face were used for the measurement of temperature. These thermo-couples were thus perpendicular to the isothermal planes of the brick, and, therefore, the accuracy of their measurements must have been seriously vitiated by conduction along the wire, with the consequent cooling of the junction (9).

In a paper to the Faraday Society Griffiths (10) reviewed some of the previous work, and proceeded to describe a method for the determination of the conductivity of bricks made from diatomaceous earth. The principle of the method is similar to the foregoing, but especial precautions appear to have been taken with the flow calorimeters. Perhaps the chief feature of the method was a device for obtaining an even temperature at the hot surface. A cast-iron tray contained some metal (say, tin) which was kept molten by means of an evenly distributed heating coil attached to the under surface of this tray. It was found to be an easy matter to maintain this molten metal at a constant temperature, which was regulated and measured by means of a bent, movable thermo-couple, sheathed in a quartz protecting tube. The face of the brick was held in such a position as to touch the surface of the molten metal.

An interesting attempt to measure the heat term by means of an air calorimeter has been made by Hepplewhite (11). Since but one result has so far been reported, also since the description of the apparatus is somewhat inadequate, it is not possible to form an estimate of its value.

B.—Methods in which the heat term is measured without the use of a calorimeter.—Clement and Egy (12) made a series of interesting experiments on the conductivity of fireclay material in the shape of hollow cylinders. The heating was obtained by means of a coil of nickel wire wound round a porcelain core and fixed axially to the specimen. The heat factor was determined by noting the electrical energy dissipated in this heating coil per unit time, after the stationary state had been attained. The temperatures of the inner and outer faces of the cylinder were determined by thermo-elements. The method is, no doubt, theoretically sound, but it is very unsatisfactory from a technical point of view, since the necessity for the construction of special test-pieces introduces serious difficulties. Very few observations concerning the nature and composition of the material were made.

Examination of the results of methods A and B.—The following statements of general interest can be made from a consideration of the aforementioned investigations:

(1) In the case of silica and fireclay materials, the thermal conductivity increases with temperature.

(2) In the case of magnesite bricks, the thermal conductivity does not increase with temperature. The bulk of the evidence points to a decrease (Dougill, Hodsman, and Cobb; Goerens).

(3) The thermal conductivities of fireclay and silica materials, although varying with different materials, are, nevertheless very similar to each other. The conductivity of magnesite is approximately four or five times that of either silica brick or firebrick (Dougill, Hodsman, and Cobb; Goerens).

(4) Comparing the results for silica bricks obtained by Dougill, Hodsman, and Cobb, and those for bricks made from diatomaceous earth by Griffiths, it seems that the latter material has but one-seventh the conductivity of silica brick, at temperatures below 800°C. Although it is not disputed that there is a great difference between these two conductivities, this large disparity is open to question.

(5) From Wologdine's work it appears that higher temperatures of firing increase the conductivity. Dougill, Hodsman, and Cobb gave two results which uphold this statement.

(6) According to Wologdine, the conductivities of carborundum and graphite are four or five times as great as those of silica and fireclay materials.

C.—Method based on Fourier's linear diffusion equation—Heyn, Bauer, and Wetzel (13) were not satisfied with the calori-

metric methods, mainly because of the uncertain nature of the effective area of heat transmission. They sought the use of a mathematical analysis as the basis of their work. Fourier's linear diffusion law made this possible. This standard equation for the linear flow of heat may be stated:—

$$\frac{d^2\theta}{dx^2} = k\frac{d\theta}{dt} \qquad (2)$$

where θ denotes temperature, x distance from a hot surface, and t time; k is a constant known as diffusivity. By using a specially constructed, electrically heated furnace, these investigators were able to heat a wall of nine bricks. Under known conditions the gradient of temperature and the rate of rise of temperature at definite distances from a hot face were measured by thermo-couples. These data formed the basis of a graphical solution of equation 2; no measurement of the heat factor being necessary. The results obtained by these experimenters were much lower than those determined by calorimetric means. The conductivity of magnesite was found to be slightly lower than that of silica and fireclay brick, and to increase with temperature. Since the theory and results of the present investigation are comparable with those of Heyn, Bauer, and Wetzel, further discussion will be left until later.

Theory of the Present Investigation.

The present work is also based on Fourier's theory of the linear diffusion of heat. Consider a wall of material in which the hot face is maintained at θ_0. Suppose that the temperature of an isothermal plane—*i.e.*, parallel to the hot face plane—at a distance x from the hot face after a time t is θ. Now, if we apply the limiting conditions that $\theta=\theta_0$ when $x=o$ and $\theta=o$ when $t=o$ to equation 2 we obtain a solution:—

$$\theta=\theta_0\left(1-\frac{2}{\sqrt{\pi}}\int_0^{\frac{x}{2\sqrt{kt}}} e^{-B^2}\,dB\right) \qquad (3)$$

$$\text{where } B=\frac{x}{2\sqrt{kt}}$$

This can be stated in the form:—

$$\frac{\theta_0-\theta}{\theta_0}=\frac{2}{\sqrt{\pi}}\int_0^{\frac{x}{2\sqrt{kt}}} e^{B^2}\,dB \qquad (4)$$

The probability integral—*i.e.*, the right-hand side of equation 4—can be reduced to an infinite series. However, since it has been

TABLE I.

Material	Percentage Porosity	Percentage Analysis		Temp. Range	Mean Thermal Conductivity	Investigator(s)
		SiO_2	Al_2O_3			
Firebrick	30	66	29	200°—1000°C.	0·00400	Wologdine
Firebrick	30	67·5	28·2	0°—1000°C.	0·00251	Goerens
Firebrick	23·3	66	31	420°—1100°C.	0·00330	Dougill, etc.
Clay Product ..	—	53	43	100°—1025°C.	0·00262	Boyd Dudley
Clay Product ..	—	53	45	0°—1000°C.	0·00211	Goerens
Fireclay Material ..	—	—	—	400°—700°C.	0·00265	Clement and Egy
Firebrick	—	71	24	200°—1000°C.	0·00117	Heyn, Bauer, and Wetzel

evaluated (14) such a procedure is unnecessary for the present work. Thus, by obtaining the value of $\frac{\theta_0-\theta}{\theta_0}$ the value of $\frac{x}{2\sqrt{kt}}$ can be computed. From this, k, the diffusivity, is easily determined. This factor is defined by Preston as "measuring the change in temperature that would be produced in a unit volume of the substance by the quantity of heat which flows in unit time through unit area of a layer of unit thickness having unit difference of temperature between its faces." A more concrete significance is given by the equation—

$$\text{Thermal conductivity} = k.c.s. \quad (5),$$

where c is the apparent specific gravity of the material and s its specific heat. The product $c.s.$ is, thus, the heat capacity per unit volume of the material.

Experimental Considerations.

The theory of the experiment presupposes the following conditioning factors:—

(1) The maintenance of an even and constant temperature on the hot face from the beginning to the end of the experiment.

(2) The accurate measurement of the rate of rise of temperature for any isothermal plane at a known distance from the hot face.

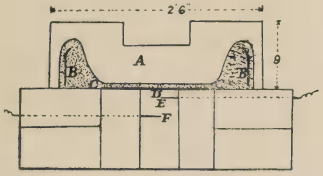
Nine rectangular bricks (9 in. by $4\frac{1}{2}$ in. by $2\frac{1}{2}$ in.), which for practical purposes are identical in all respects—*i.e.*, size, shape, composition, and burning, &c.—are chosen. These are built to form a wall such that their lengths indicate the direction of flow of heat. Each brick is laid on a very thin layer of ground brick material, thus helping in some degree to preserve the continuity of like material. The central brick of this wall is regarded as the test material. At fixed distances from a specified face (which is known as the hot face) say, 5 cm. and 8 cm., two holes, about $\frac{3}{16}$ in. in diameter, have been drilled into this brick, parallel to the face, so as to reach the centre of the brick. Into each of these holes a platinum—platinum-rhodium thermo-couple has been placed so that it reaches the brick material at the end of the hole. In order to keep the thermo-couples in position, and, further, with the object of remedying any disturbance of the heat flow, these holes have been filled with ground brick. The thermo-couples have been taken by way of small grooves through the brick structure in a direction parallel to the hot face.

The face temperature is measured by means of a thermo-couple fixed in the centre of the hot face of the test brick. To do this effectively the thermo-couple wires are carried along very narrow grooves cut in the face of the brick; while the junction fits into the small hole made at the intersection of the grooves. The couple, which is kept in position by means of a little fire cement, is carried

along the hot face, along the top of the structure, and thence to a unipivot galvanometer. A structure of firebricks (*vide* Figs. 1 & 2)

Fig. 1.

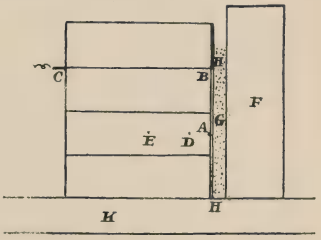
Cross-Section through Plane of Thermo-Couple Holes parallel to the Base of Apparatus.



A, furnace part of refractory clay.
B B, electrodes.
C C, hot plate.
D, face thermo-couple.
E, 1st hole thermo couple.
F. 2nd hole thermo-couple.

Fig. 2.

Cross-Section perpendicular to the Plane of the Thermo-Couple Holes.



A D E, position of three thermo-couples.
A B C, shows the path of the face of thermo-couple.
F, furnace part.
G, graphite resister.
H H, hot plate
K, base of apparatus.

is built round the experimental wall, and the "hole" thermo-couples, after being carried through this structure, are connected by means of compensating leads to two recording galvanometers.

A bauxitic plate, somewhat larger in area than the face of the nine bricks, and placed with a clearance of about $\frac{1}{4}$ in. from this face, is used to maintain the temperature. It forms the central constricted portion of a carbon resistance furnace, which is similar in principle to the standard Hirsch refractory testing apparatus. Finely-divided graphite is used as the resister, and iron plates, 12 in. by 5 in., which are bent in the middle to fit the furnace, serve as electrodes.

At the beginning of the experiment, in order to reach the desired face temperature as quickly as possible, the amperage is raised considerably. When the temperature is attained after approximately one hour, it is maintained constant for about nine hours at a much reduced amperage. A switch near to the furnace helps very much in this work. The temperatures of the two isothermal planes are continuously recorded ; but with the object of reading all temperatures on one instrument they are taken every hour on the unipivot galvanometer which regulates the face temperature. This facilitates the checking of the couples against the melting points of standard substances—*i.e.*, tin, potassium dichromate, common salt, copper, and potassium sulphate.

In the earlier experiments it was noted that results obtained from the first heatings were not concordant with those obtained in later heatings with the same bricks. In the case of three batches of material (two fireclay and one magnesite), the results of the first

heatings were high. In two other cases (one silica, one fireclay) they were low. To obviate such discrepancies the brick face is subjected to a continued heating for over twelve hours at a temperature of 1100°C. The results obtained after this treatment agreed well. The fact that the bricks have been fired at temperatures far higher than those at which discordance is noted, is of some significance. Heyn, Bauer, and Wetzel (16) also reported phenomena similar to the above.

To check the constancy of the hot face temperatures, a number of experiments were conducted in which five thermo-couples were placed flush with the hot face of the specimen brick—one at each corner and one in the centre. After two hours' heating, the difference of temperature encountered was never greater than 10° C.

In the calculation of the results, the temperature obtained after a period of about nine hours is taken. Theoretically, the time factor depends upon commencing the experiment with the desired hot face temperature. Practically, as already mentioned, such a temperature is not obtained until a period varying from 0·7 to 1·5 hours has elapsed. A correction is therefore necessary. This cannot be computed accurately, because the initial conditions are not in keeping with those set down in the Fourier's analysis. Calculations based on the theory of the experiment and the temperatures observed at the end of the initial period indicate an empirical correction amounting to about 0·3 hours when the initial heating is under one hour, and 0·4 hours when this heating is between 1 hour and 1·5 hours. This approximation cannot introduce any appreciable error into the results, since the time factor used in the calculation is about nine hours, and after such a time the rate of rise of temperature is rarely more than 10°C. per hour—*i.e.*, the time factor is measured quite as accurately as the temperature factor.

Calculation of Results.

It will be seen from a previous section that the temperature, time, and distance factors of only one isothermal face are necessary for the calculation of a result. The data obtained from the other isothermal face can be used as a check.

The following will illustrate the method of computing these results:—

Silica Brick.

Face temperature measured by thermo-couple A.
First hole ,, ,, ,, ,, ,, B.
Second hole ,, ,, ,, ,, ,, D.
Distance of first hole from hot face = 4·0 cm.
,, second ,, ,, ,, = 5·4 cm.
Hot face maintained at 1000°C. (galvanometer reading).
First hole temperature reached 735°C. (galvanometer reading) at the end of experiment.

TABLE II.—RESULTS.—*Silica Material.*

Mark	Percentage Porosity	App. S.G.	True S.G.	Percentage Analysis					Temp. Range	Mean Diffusivity	Mean Thermal Conductivity
				SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO			
A1.	24·0	1·75	2·30	95·40	0·90		1·68		586°— 816°C. 655°— 921°C. 739°—1028°C. 827°—1138°C.	0·00177 0·00186 0·00194 0·00211	0·00086 0·00097 0·00107 0·00123
A2.	24·0	1·75	2·30	95·40	0·90		1·68		518°— 816°C. 572°— 921°C. 654°—1028°C. 732°—1138°C.	0·00187 0·00190 0·00200 0·00219	0·00090 0·00096 0·00107 0·00124
A3.	22·3	1·80	2·31	95·40	0·90		1·68		486°— 703°C. 637°— 906°C. 714°—1008°C. 798°—1114°C.	0·00186 0·00202 0·00206 0·00239	0·00088 0·00106 0·00115 0·00141
A4.	22·3	1·80	2·31	95·40	0·90		1·68		410°— 703°C. 541°— 906°C. 605°—1008°C. 658°—1114°C.	0·00202 0·00217 0·00219 0·00228	0·00094 0·00110 0·00119 0·00129
B	38·2	1·51	2·44	94·02	1·78		2·64		610°— 815°C. 704°— 924°C. 790°—1032°C. 894°—1142°C.	0·00265 0·00286 0·00312 0·00345	0·00114 0·00130 0·00150 0·00177
C	20·7	1·84	2·32	93·36	2·97		2·20		661°— 903°C. 733°—1005°C. 829°—1114°C.	0·00212 0·00229 0·00238	0·00115 0·00131 0·00145

TABLE III.—RESULTS—*Firebricks.*

Mark	Percentage Porosity	App. S.G.	True S.G.	Percentage Analysis					Temp. Range	Mean Diffusivity	Mean Thermal Conductivity
				SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO			
D.	17·3	2·03	2·46	68·38	26·12	2·50			508°— 788°C. 584°— 891°C. 657°— 996°C. 740°—1096°C.	0·00224 0·00237 0·00251 0·00278	0·00124 0·00139 0·00154 0·00187
E.	15·9	2·00	2·36	57·90	32·96				608°— 822°C. 693°— 927°C. 785°—1030°C. 892°—1138°C.	0·00211 0·00220 0·00263 0·00303	0·00119 0·00136 0·00167 0·00206
F.	24·6	1·92	2·55	67·49	27·15				498°— 786°C. 568°— 890°C. 650°— 994°C. 733°—1098°C.	0·00215 0·00227 0·00244 0·00267	0·00113 0·00124 0·00142 0·00164
Retort Material.											
G.	24·5	1·85	2·45	67·10	27·17				492°— 787°C. 560°— 890°C. 634°— 994°C. 716°—1098°C.	0·00192 0·00207 0·00215 0·00234	0·00096 0·00110 0·00117 0·00136
H.	28·2	1·88	2·62	65·70	28·47				532°— 786°C. 608°— 892°C. 680°— 994°C. 767°—1098°C.	0·00233 0·00248 0·00253 0·00276	0·00119 0·00134 0·00145 0·00168
I.	24·7	1·91	2·54	72·46	23·65				554°— 786°C. 634°— 892°C. 713°— 994°C. 796°—1098°C.	0·00308 0·00322 0·00341 0·00365	0·00162 0·00182 0·00198 0·00226

TABLE IV.—RESULTS—*Magnesite Material.*

Mark	Percentage Porosity	App. S.G.	True S.G.	Percentage Analysis					Temp. Range	Mean Diffusivity	Mean Thermal Conductivity
				SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO			
J.	20·0	2·63	3·29	—	—	1·87	5·24	81·79	509°— 703°C. 586°— 806°C. 647°— 909°C. 717°—1012°C.	0·00214 0·00204 0·00186 0·00181	0·00174 0·00174 0·00166 0·00167
K.	20·0	2·63	3·29	—	—	1·87	5·24	81·79	545°— 806°C. 606°— 909°C. 712°—1116°C.	0·00217 0·00213 0·00171	0·00182 0·00188 0·00162
L.	24·5	2·56	3·38	—	—	2·56	4·68	87·88	510°— 690°C. 572°— 786°C. 644°— 890°C. 708°— 991°C. 766°—1097°C.	0·00352 0·00314 0·00310 0·00299 0·00268	0·00285 0·00265 0·00273 0·00274 0·00255

Second hole temperature reached 648°C. (galvanometer reading) at the end of experiment.

Corrections make hot face temperature = 1028°C.
,, ,, first hole ,, = 739°C.
,, ,, second hole ,, = 654°C.
Corrected time for the period of experiment = 8·8 hrs.

Considering the first isothermal face—

$$\frac{\theta_0 - \theta}{\theta_0} = \frac{2}{\sqrt{\pi}} \int_0^{\frac{x}{2\sqrt{kt}}} e^{-B^2} dB$$

and $\frac{\theta_0 - \theta}{\theta_0} = 0{\cdot}2821$

from the evaluation of the probability integral

$$\frac{x}{2\sqrt{kt}} = 0{\cdot}2556$$

$\therefore k$ (diffusivity) = 6·960
= 0·00194 in C.G.S. units.

and since thermal conductivity = $k.c.s.$
,, ,, = 0·00107.

Similarly, considering the second isothermal face—

Thermal conductivity = 0·00107.

In the calculation of the conductivity of fireclay and silica material from the diffusivity, the data of specific heat were obtained from measurements made by Bradshaw and Emery (17). They showed that the specific heat of these materials increases with temperature, which fact has been recognized in all the computations. In connection with the work of magnesite, it was found necessary to determine the specific heat of this substance at temperatures up to 1100° C. The values of this "constant" also increase with temperature, and are higher than those of silica or fireclay material. The high specific heat and specific gravity of magnesite give a comparatively very high value for the heat capacity per unit volume of this substance.

Texture of Experimental Material.

Before proceeding to any discussion of the results, it will be as well to describe the textures of the various materials.

A_1, A_2, A_3, A_4.—*Silica brick*.—Texture very open. Many large and sub-angular rock fragments. Bonding of coarse and fine fairly good, although adherence of some of the grains is only fair. Abundant large fissures.

B.—*Silica brick*.—Exceptionally fine-grained, close texture. Major portion of material of sand size. Fragments of rock of appreciable size scarce. Those seen vary from round to sub-

angular. Texture uniform throughout brick. Very appreciable porosity, but pores seem to be of even size. Friable.

C.—Silica brick.—Texture fairly open. Large proportion of angular rock fragments, which vary in size from $\frac{1}{4}$ in. downwards. Bonding of coarse and fine fairly good. Fine material, easily detached. Large number of fissures of appreciable size.

D.—Firebrick.—Close structure. Not much clay grog, but large proportion of angular quartz grains. Adherence very good. Very few fissures. Quartz grains very evenly graded; possibly all would pass an 8's lawn. Faces of brick not good. Very fine black cores. Appearance of many pinholes.

E.—Firebrick.—Very close structure. Abundance of fine grained rounded grog. A little larger grained grog can be detected. Adherence exceptionally good. Marked by a fair number of black cores, generally with cavities. Faces smooth, edges sharp.

F.—Firebrick.—Very open texture. Abundance of rounded clay grog of uneven grading, some grains approximating to pebbles. Unweathered pellets detected. Adherence poor—in fact, material is very friable. Highly fissured.

G.—Retort material.—Very open texture. Very heavily grogged with medium to fine rounded material of uneven grading. Abundance of small fissures. Adherence of grog very poor. Matrix appears to have contracted away from the grog.

H.—Retort material.—Somewhat closer in texture than G. Heavily grogged with rounded material of slightly more even grading than G. Adherence as a whole fairly good, although some grains are easily detached. Some fissures. Very white colour with well-defined skin.

I.—Retort material.—Very close in texture. Abundant grog which, tending to be rounded, is evenly graded, Possibly some quartz fragments. Black cores present, but scarce. Tendency towards layering. Fissures, present but scarce, are parallel to outside faces. Superficial skin. Signs of possible reduction towards end of fire.

J and K.—Magnesite bricks.—Two bricks of the same batch. Texture very close.

L.—Magnesite brick.—Texture not so close as in J and K.

Discussion of the Results.

A_1, A_2, A_3, A_4, represent the results obtained from two different specimens of a well-known brand of silica bricks. A_1 and A_2 represent the results from two isothermal planes in the one brick; A_3 and A_4 two isothermal planes in the other brick. A_1 is 4·0 cm., A_2 5·4 cm. respectively from the hot face of No. 1 specimen, A_3 and A_4 4·3 and 6·4 cm. respectively from the hot face of No. 2 specimen. In the measurement of the temperatures of No. 1 specimen a different set of thermo-couples from those used in No. 2 specimen gave the temperature readings. The results indicate in some degree the

error of experiment. It cannot be assumed, however, that the material factor in any one series is the same. This factor has been known to vary appreciably within the same brick. It should be mentioned that in every series of experiments reported in this paper the results obtained from the second isothermal face are slightly higher than those obtained from the first. An explanation of this may lie in the disturbing effect of the first hole, but nothing definite has been settled on this point.

The results are generally much lower than those obtained by "calorimetric" experiments, but they agree well with those obtained by Heyn, Bauer, and Wetzel, except in the case of magnesite. These latter investigators showed magnesite to possess a thermal conductivity which was slightly lower than that of firebrick, and which increased with temperature. Dougill, Hodsman, and Cobb, Goerens, and Boyd Dudley showed that, besides being four or five times greater than that of firebrick, the thermal conductivity of magnesite decreased with temperature. The present investigations indicate that magnesite has in general a greater conductivity than firebrick at temperatures below 1000°C., but it decreases with temperature. Much difficulty attached itself to the magnesite measurements, since they seemed to vary considerably with the nature and amount of the heating of the hot face. It was only after a considerable heating that concordant results were obtained. The initial experiments on the material J showed a conductivity 70 per cent. greater than the reported value. L, however, was not so difficult, and gave the reported results after twelve hours' soaking.

Texture, Porosity and Conductivity.

It has been suggested that there is a relationship between thermal conductivity and porosity. While such a statement cannot be refuted (for, in part, it must be true), its limitations should be frankly recognized. In so far as the pore spaces act as insulators, thus impeding the passage of heat, they have an influence on thermal conductivity. The term porosity is used to indicate a measure of the pore spaces, which, naturally, vary in size from easily perceptible fissures to microscopic holes. The property of "pore space" insulation depends upon many factors, some interrelated, including temperature and the disposition, size, and shape of the pore spaces.

The measurement of percentage porosity does not include any knowledge of these latter factors, and, consequently, a quantitative relationship between percentage porosity and thermal conductivity is not to be anticipated. However, the results of this investigation seem to point to some connection between texture and conductivity. The silica bricks A and B are readily comparable in this respect. The fine-grained, close-textured B has a far greater conductivity than A, which possesses a coarser, more open structure. Then, again,

TABLE V.—*Variation of Conductivity with Temperature.*

Material	Mark	500°	600°	700°	800°	900°	1000°	1100°
Silica Brick	A	0.0007_5	0.0008_5	0.0009_5	0·0010	0·0011	0·0013	0·0016
,, ,, ...	B	—	0.0009_5	0·0011	0.0012_5	0.0014_5	0·0017	0·0020
,, ,, ...	C	—	0.0008_5	0·0010	0·0012	0.0013_5	0·0015	0.0016_5
Firebrick	D	0·0010	0.0011_5	0·0013	0·0015	0.0016_5	0.0018_5	0·0025
,, ...	E	—	0·0010	0·0012	0·0014	0·0016	0.0019_5	0·0024
,, ...	F	0·0010	0·0011	0·0012	0.0013_5	0·0015	0.0017_5	0·0021
Retort Material	G	0·0008	0·0009	0.0010_5	0·0012	0·0013	0·0014	0.0017_5
,, ,, ...	H	0.0009_5	0·0011	0.0012_5	0·0014	0·0016	0.0017_5	0·0021
,, ,, ...	I	0.0012_5	0.0014_5	0·0017	0.0019_5	0·0021	0·0023	0·0027
Magnesite Brick	J	0.0017_5	0.0017_5	0·0017	0·0017	0.0016_5	0.0016_5	0·0016
,, ,, ...	L	0·0029	0.0028_5	0·0028	0.0027_5	0·0027	0·0026	0·0025

TABLE VI.—*Variations of Diffusivity with Temperature.*

Material	Mark	500°	600°	700°	800°	900°	1000°	1100°
Silica Brick	A	0·0017	0·0018	0·0019	$0·0019_5$	0·0020	0·0022	$0·0025_5$
Silica Brick	B	—	0·0024	0·0026	0·0028	0·0030	$0·0033_5$	0·0037
,, ,, ...	C	—	$0·0017_5$	$0·0019_5$	0·0022	0·0023	0·0024	$0·0025_5$
Firebrick	D	0·0020	$0·0021_5$	0·0023	0·0025	0·0026	0·0027	0·0034
,, ...	E	—	0·0019	$0·0021_5$	$0·0023_5$	0·0025	0·0029	0·0034
,, ...	F	0·0021	$0·0022_5$	0·0022	$0·0023_5$	$0·0024_5$	0·0027	0·0031
Retort Material	G	$0·0017_5$	$0·0018_5$	0·0020	0·0022	0·0022	0·0023	$0·0026_5$
,, ,, ...	H	$0·0020_5$	$0·0022_5$	0·0024	$0·0025_5$	$0·0026_5$	$0·0027_5$	0·0031
,, ,, ...	I	$0·0026_5$	0·0029	0·0032	$0·0034_5$	0·0035	0·0036	0·0040
Magnesite Brick	J	0·0023	$0·0021_5$	0·0020	0·0019	$0·0017_5$	0·0017	0·0016
,, ,, ...	L	0·0038	0·0035	0·0033	$0·0030_5$	0·0029	$0·0026_5$	$0·0024_5$

a comparison of the results for fireclay materials indicates the possibility of this inference. I, D, and E have greater conductivities than F, G, and H; I, which is the closest-textured material being well to the fore. It might be argued that the material of closer texture offers a more continuous passage for the heat along the solid matter, thus eliminating, to some degree, the necessity for radiation jumps or tortuous paths. Experiments, in which an effort is being made to define a relationship between texture and thermal conductivity, are now in progress.

In the case of practically all the silica and fireclay materials examined, when the hot face is at 1100°C. there has been noted a greater increase in conductivity than is consistent with a "straight line" relationship between conductivity and temperature. While an explanation of this observation may be sought in the variation of the properties of the solid material with temperature, the effect of pore spaces at the higher temperatures cannot be ignored. Dr. Mellor (18) has already suggested that the radiation across the pore spaces at high temperatures is likely to be comparable with the conduction through the solid material. Dougill, Hodsman, and Cobb (19), while not refuting the principle upon which Mellor's deduction was based, have given a calculation indicating that the temperature at which the rate of radiation of heat across a pore space of 0·01 cm. is equal to the rate of conduction across a similar width of solid material, is over 3600°C. Such a temperature is well above the fusion range of the material, and, consequently, these investigators conclude that at the ordinary temperatures obtaining in industrial practice the insulating properties of the pore spaces are always maintained. Considering the conductivity results reported in this paper, which are much lower than those given by Dougill, Hodsman, and Cobb, we may be led to believe that some of the pore spaces at high temperatures (1400° to 1500°C.) lose their insulating properties, and even at a temperature of 1100°C. have the capacity for transmitting heat at rates comparable with the solid matter. Following the argument of the aforementioned investigators, consider the transference of heat across the parallel-faced section (material of width d) by conduction and the transmission by radiation across a similar shaped air space. Suppose the two faces of the section in each case to be at θ_1 and θ_2 then the quantity of heat transmitted by conduction is

$$Q_1 = \frac{k(\theta_1 - \theta_2)}{d} \text{ calories per sq. cm. per sec.}$$

The Stefan-Boltzmann equation for radiation is

$$Q_2 = \sigma (\theta_1^4 - \theta_2^4) \text{ calories per sec.}$$

where σ is the radiation constant.

Suppose that $Q_1 = r\,Q_2$,

then $$\frac{k(\theta_1 - \theta_2)}{d} = r\,\sigma\,(\theta_1^4 - \theta_2^4).$$

When θ_1 and θ_2 are almost equal

$$r = \frac{2k \times 10^{11}}{d\,\theta^3}$$

since $$\sigma = 1{\cdot}28 \times 10^{-12}.$$

Now considering the case in which we have a temperature of 1030°C., that is, 1300° A, d=0·05 cm. and k=0·0015

$$r = 2{\cdot}88$$

that is, the rate of heat transmission by conduction across the solid material is 2·88 times that by radiation across the pore spaces.

When $\theta = 1130$°C.—that is, 1400°A—and d=0·05 cm. and $k = 0{\cdot}0015$

$$r = 2{\cdot}1.$$

Taking another case

$$\theta = 1030°\text{ C.}, d = 0{\cdot}01\text{ cm.}, \text{ and } k = 0{\cdot}0020$$

$$r = 18{\cdot}2.$$

While admitting that the value of d taken is probably greater than the average pore space, experience shows that there is an appreciable amount of such space—*i.e.*, fissures and pinholes in many commercial bricks. The conclusion gained from the calculations with the results quoted in the paper is that the pore spaces at high temperature have not the great insulating capacity accorded them by some previous investigators.

The conception of diffusivity has a very particular significance in those heating systems, in which temperature is of more importance than total heat—*i.e.*, the coke-oven and the gas-retort. In the C.G.S. units used in this paper the diffusivity may be said to express the rise in temperature produced in 1 c.c. of the substance by 1 calorie in 1 second, through 1 sq. cm. of a layer 1 cm. thick, having a temperature difference of 1°C. between its faces. This definition indicates that diffusivity measures the rate of the rise of temperature produced in a material. It is instructive to compare the results of the silica material B and the fireclay material F. The thermal conductivities are very comparable; but the diffusivity of B is far greater then F. This may be interpreted to mean that, other factors being the same, material B would be far more effective in a coke-oven than material F. Material I is of particular interest, because of its very high diffusivity and thermal conductivity The results of our experiments which, of course, are directly concerned with the measurement of diffusivity, show this factor to vary with temperature in a manner similar to that of thermal conductivity (*vide* Figs. 3 and 4).

Fig. 3.

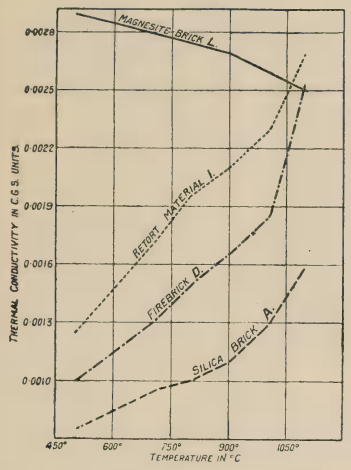
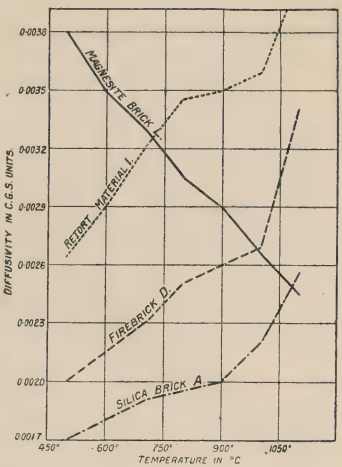


Fig. 4.



It is suggested that, in the carbonizing industries, the measurement of diffusivity would form a reliable criterion of the thermal efficiency of the material; while, in that type of furnace work where insulation is wholly desirable, the measurement of thermal conductivity would be more satisfactory.

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XXIV.—Intensifying Electro-Magnets.

By H. H. Thompson.

I have already had the pleasure of describing to this Society the "Rapid" Magnetic Separator, the use of which, I am proud to think, has now become standard practice in the Potteries.

This short paper is to introduce an attachment, which, when used in conjunction with a Rapid Separator, makes it still more efficient. We call it *The Rapid Intensifier and Amplifier.*

Owing, no doubt, to the fact that there has been nothing more efficient available, users have perforce been content with the admittedly excellent results obtained by means of the Rapid Separator. The attachment referred to, will, I am sure, be of keen interest to those enthusiasts who are always striving for still better results.

Although the Rapid Separator has been on the market for a number of years, I occasionally meet people who have heard of it but never seen it. For their benefit, if any should be present, and in this room I see some of the rising generation, I have provided illustrated circulars with a description of it.

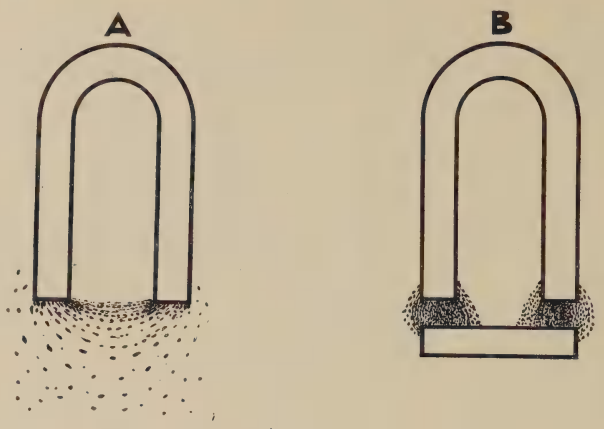
Before I demonstrate the new apparatus, there are a few remarks necessary to make the theory of it better understood. It is very simple, and I have merely harnessed an old law of magnetism. When suitably placed in position on an existing machine, it increases the intensity of the magnetic field by approximately 200/300 per cent., and may be constructed in such a manner that the number of magnetic edges are increased by approximately 100 per cent., and this without increasing the current consumption in the slightest degree, which, of course, is a very great consideration.

Most of you have, at least, a nodding acquaintance with what are known as the "lines of force" emanating from a magnet ; also what is known as the "field" of a magnet.

For the benefit of those who may not, and in order to make the theory of the apparatus more easily understood, I have prepared two diagrams.

A indicates the lines of force of the magnet when brought near a number of iron filings sprinkled on a sheet of paper. It will be observed that the lines tend to stray and are densest between the poles.

The next diagram *B* shows the effect created by placing a keeper or armature near the magnet. It will be seen that the iron particles have massed by reason of the shortening of the lines of force and the consequent intensification of the magnetic field. These would be held very much firmer than without the armature.



For the benefit of the generation of young potters who were not present when I had the pleasure of being here the last time, I wish to emphasize the fact that the smaller the particles of iron, the more difficult they are to secure and the more powerful the magnet must be.

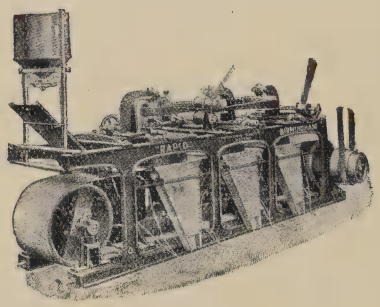


Fig. 1.

Fig. 1 is a photograph of a *high intensity separator*. In passing, I might mention that before the war the manufacture of such apparatus, which is used for the separation of feebly magnetic minerals—such as are unaffected by ordinary magnets—was practically a German monopoly, but I am pleased to say that with this apparatus we can do everything that could be done by the Germans, and some things they cannot do. It may interest you to know that we applied for a patent in Germany, where we were opposed by Krupps who were successful in the Lower Court, but we appealed and after giving a practical demonstration at the German Patent Office, in November last, we were granted the patent.

In this machine, the electro-magnets (specially powerful), are placed under the travelling feed belt. The separating discs,

or secondary magnets which continually revolve, are larger in diameter than the width of the feed belt, and, therefore, overhang the sides. The under edges of the discs are serrated, and as the intensest field of a magnet is at its edges the magnetic lines all tend to converge from the primary magnets through the belt and the feed, to the serrated edges of the discs, which are thus magnetized by induction and intensified by shortening the lines of force to such an extent that they will attract feebly magnetic particles. The latter, placed in the middle of a pole of the primary magnet which energises the separating discs, would barely be held. That portion of the revolving separating disc or secondary magnet which is over it, is therefore magnetized by induction by the primary magnet, snatches up the feebly magnetic particles and carries them gradually out of the intense field until they reach a theoretically neutral zone and are thrown off by gravitational and centrifugal force, or if too fine, are brushed off.

This machine can be tuned up so delicately that, for instance, a Monazite Sand containing the following feebly magnetic minerals, viz.: Ilmenite (Black), Garnet (Pink), and Monazite (Amber) can be perfectly separated from the mass, and from each other at one operation. Now precisely the same principles are taken advantage of in the "Rapid" Intensifier and Amplifier. I marvel now that it did not occur to me when I was engaged on the machine I have just described—some six years ago.

The apparatus really is so simple that I am afraid we shall have to publish a warning against infringement of the Patent.

It simply consists in placing over the magnets at a suitable distance an intensifier in the form of an armature.

This intensifier provides a shorter path for the lines of force and concentrates them in such a manner that, instead of tending to stray into the air, they are, as it were, harnessed.

By providing the intensifier with bars similar to those of the magnet proper, the intensification is assisted, and by induction they also become magnetic themselves; these I term Amplifiers.

I may point out that the closer the intensifier is put to the magnet without touching it, the more intense the magnetic field becomes. So much so, that particles of the mineral ore of tungsten, which are so feebly magnetic that an ordinary permanent magnet has not the slightest influence on them, (neither has the ordinary "Rapid" Electro-magnet), yet, with the intensifier in position, the latter will hold such particles.

I am, therefore, convinced that its use will enable still better ware to be made (of course, I refer only to iron specks).

Where owing to the lay-out of the sliphouse it is not possible to install the inclined magnet trough without raising the sifters (which in many cases means also lifting the roof), and one has perforce to continue to use the old potters magnets, the intensification of the magnetic field can be effected by magnets specially

designed, but, of course, it will not compare with the electro-magnet even minus the intensifier.

I might also add that the more powerful the primary magnet, the easier it is to judge the benefit of the apparatus.

I have for that reason brought a more powerful magnet than we use in our standard apparatus, although two firms in the Potteries have magnets of the same strength at work.

Whatever the strength of the primary magnet the intensification will be effected in proportion.

When I was last here, Mr. C. E. Ramsden asked if we could offer any apparatus that would extract chalcopyrite and iron pyrite from clays and Mr. J. A. Audley made some remarks on the same subject.

At the time we did not manufacture any apparatus capable of doing this, but the ore separating machine I have described will do this. I stated then, and am still of opinion that the operation, which is a dry separation, would be too costly to install and too slow in operation for the pottery trade, and consequently I have not put it forward as a serious proposition.

I am, however, now rather hopeful, that, providing the clay containing chalcopyrite and iron pyrite can be treated in the slop state, the intensifier I have described, in conjunction with a specially powerful Rapid Separator, would create a sufficiently intense field to secure such impurities, and at a quarter of the cost of the ore separating machine.

In this respect, if Messrs. Audley and Ramsden, or anyone else will provide the material for testing in the slop state, I should be pleased to go deeper into the matter, and if necessary, to make an apparatus sufficiently powerful, assuming that the cost does not prohibit any chance of its being used.

It has to be borne in mind that, in a wet process, one has to contend against the flow of liquid endeavouring to wash these feebly magnetic particles off the magnet.

This can, of course, be largely mitigated by making the apparatus very powerful and wide enough to treat a large bulk by means of a very thin stream, but with the drawback of increased initial cost and current consumption.

DISCUSSION.

Mr. B. J. Moore :—It gives me very great pleasure to propose a vote of thanks to Mr. Thompson for his paper. I feel that he is an old friend of the Society, because I remember he came along some years ago with a very practical piece of apparatus which has proved itself to be one of the greatest boons in the Potteries. I suppose it is one of the most difficult things to clean a pottery slip efficiently, and though I have always felt that the rapid magnetting machine has been very good as it stands, there are one or

two claims that the proprietors make for it with which I do not altogether agree. They have always said, for instance, that every particle of iron must get into the magnetic field and be abstracted. That I cannot agree with, because, as Mr. Thompson has pointed out, the extraction of magnetic material from a liquid is, at least, difficult. It is still more difficult when you come to deal with pottery slip that has to be sifted, and sifted thick. I think that anyone who has had any experience of sliphouse work will agree with me that you cannot clean a pottery slip unless you sift it thick, and the thicker you sift it the more difficult it becomes to abstract the magnetic particles from it. I, therefore, welcome any apparatus of the kind that Mr. Thompson has described, which, in addition to increasing the magnetic strength of the apparatus, offers further magnetic points which will help to break up the slip and bring any magnetic particles into direct contact with the magnets themselves.

Mr. B. J. Allen :—I have pleasure in seconding the vote of thanks to Mr. Thompson. I think that one of the greatest advantages of the latest improvement in the rapid magnetting machine is the closeness of the amplifier to the original magnetic separator. I think it compels the user to employ a comparatively thin stream of liquid, and in that way I feel that the results will be more efficient than passing over a thick stream of slip, which very often occurs in pottery practice.

Mr. Thompson :—In regard to Mr. B. J. Moore's remarks about thick slip, I quite agree that it is more difficult to remove the iron from thick slip than it is from thin. But, if I were a potter, instead of putting the separator at about 5 inches to the foot fall, I should tip it up much more steeply. I know that may sound ridiculous, for I remember when the rapid magnetting machine was first brought into the Potteries it was put to me that the flow was altogether too fast. I am perfectly certain, however, that the more you tip up the trough, providing you also allow extra width to get the same amount of material over, the better chance you have of magnetting a thick slip as efficiently as you would a thin slip. You must, of course, have a magnet sufficiently wide to get a sufficient stream of slip to hang on to the magnet all the time. I do not know whether there is a machine working in the Potteries to-day at such an angle as I have mentioned. I have seen machines working at various angles, but I have never yet seen one working at an angle that I would like.

Correspondence.

We have received a communication from the American Dressler Tunnel Kilns, Inc., of Cleveland, O., referring to the paper: "Combustion of Fuel Oil; with a Description of an Oil-Gas Furnace," by Percival J. Woolf (page 161 of this volume).

In justice to all concerned, we deem it advisable to publish this letter, together with the replies, in full. [Editor.]

Editor,
Transactions of The Ceramic Society,
Stoke-on-Trent,
England.

Dear Sir:—

I have before me 'Transactions of The Ceramic Society,' volume XXI., Part 11, and have read the article on—

'Combustion of Fuel Oil; with a description of an Oil-Gas Furnace....Percival J. Woolf.'

on pages 161 and following.

Without going into a lengthy discussion as to the statements made regarding the kiln *per se*, I think that in justice to your readers, and in the interest of truth, they should be made aware of the following:—

1. The Lenox Pottery Kiln referred to never was successful in burning any but a few experimental pieces. Repeated efforts were made to use it commercially, but it could not be made to work and was discarded.
2. This and the Westinghouse Kiln referred to on Page 178 are the only two kilns of that type that were ever built; the company selling and manufacturing them has gone into the hands of a receiver.
3. On page 180, Mr. Woolf said: "We have three kilns in New Castle, Pa. using oil." This is not the case. There are only two tunnel kilns of any type in or near New Castle, Pa. Both are Dressler Kilns and both are burning gas.
4. In the same paragraph, Mr. Woolf states: 'We have one in the same neighbourhood as the Lenox Kiln.....utilizing oil.' The only other Tunnel Kiln in the neighbourhood is the Dressler Kiln, at the plant of the Mutual Potteries Co., burning gas.
5. In the same paragraph, Mr. Woolf, states: 'We have probably in the neighbourhood of six other kilns, working on malleable steel to 2000°F., all of them using our gas vaporizers.' There are no Tunnel Kilns in the U.S. working on malleables, excepting the Dressler Kiln. In

some of these, we use oil and some gas.

Yours truly,
AMERICAN DRESSLER TUNNEL KILNS, INC.,
Philip Dressler,
Chief Thermal Eng.

May 18th, 1922.

P. Dressler, Esq.
American Dressler Tunnel Kilns,
1740, East 13th Street,
Cleveland,
Ohio.

Dear Mr. Dressler,

I am in receipt of your letter of the 6th inst., regarding the article on—

'Combustion of Fuel Oil, with a description of an Oil-Gas Furnace....Percival J. Woolf.'

and am very much obliged to you for writing to me. I will have your letter inserted in the Transactions of the Ceramic Society after giving Mr. Woolf an opportunity of replying to same.

Yours faithfully,
J. W. Mellor.

J. W. Mellor, Esq.,
The Ceramic Society,
Central School of Science and Technology,
Stoke-on-Trent,
England.

Dear Sir,

Mr. Campbell wrote you on the 29th ulto., sending you enclosures, but my letter to you of the 2nd of June was evidently omitted, and I am giving you a copy of this letter, which answers, although somewhat unsatisfactory, the letter of Mr. Dressler's of the American Dressler Tunnel Kilns. Owing to the complications due to the fact that the General Combustion Company in the States is non-existant and the impossibility of obtaining access to their records, we cannot answer these questions in such a manner as would be agreeable to both you and myself.

The writer still has as much faith in this particular type of kiln but conditions are not ripe to exploit it. The principle has been proven and it is a question of working out the mechanical

details, which we feel sure have now been satisfactorily solved.

Yours very truly.
Percival J. Woolf.

Montreal,
June 2nd, 1922.

J. W. Mellor, Esq.,
Stoke-on-Trent, England.

Your letter of the 18th, enclosing copy of letter from Mr. Dressler to hand, and I would state the following :—

1. The Lenox Pottery Kiln has shown that the principle is a success—Mechanical structural details occurred and owing to the inability of the General Combustion Co. to further finance this kiln, the necessary structural details were never completed by the General Combustion Co.
   I have a letter, however, from Mr. Kirk, which we quote as follows :—
   'The Kiln at the Lennox Plant is ready to operate and I believe, will successfully turn out their glost ware, and will also now fire their biscuit ware. However, it is entirely too short to give good results on biscuit ware, as the cars come out too hot at the delivery end.
   The reason it has not been tried out is because the Lenox people insist on the General Combustion Co. fulfilling their obligations. What the General Combustion claim is, that they cannot carry out any further work on the kiln until the Lenox Company help in the financing and it is this state of affairs which has driven the General Combustion to the wall and left the furnace in its present state.
2. The Plant of the Universal Sanitary Company, which is operated by the patentee of the compensated twin chamber tunnel kiln, has used the same method of burning as advocated in this paper. As explained already, it is immaterial whether you use oil or gas on these burners, as they are equally applicable for both.
3. Our records here are incomplete and I an unable to find the name of the kiln which is of the tunnel type, but not of the twin chamber, which is using oil-gas. I will, however, secure this information as soon as possible.
4. Our records show that the Dressler Company installed kilns in the Saginaw Malleable Co., Saginaw, Mich., and two of the plants of the Natioual Malleable in Cleveland, O., using oil-gas burners. This information is not necessarily conclusive, and I am unable to answer them more definitely until I can communicate with the Receivers of the Gen. Combustion Co. in Chicago.

Yours very truly,
P. J. Woolf.

Reviews.

Handbook of Ceramic Calculations.

By A. Heath & A. T. Green. (Hughes & Harber, Stoke.on-Trent, 1922.)

Although most of the calculations which arise in the manufacture of pottery involve nothing beyond simple arithmetic, it is convenient, not only to the student, but also to the official on the works, to have available the most rapid methods of attaining the desired results. This remark applies to such problems as the determination of porosity and specific gravity, both of solid materials and slips, the preparation and mixing of slips and bodies, the calculation of molecular formalae and their application to glazes and bodies and the blending thereof, the proximate analysis of clays and the determination of the degree of fineness by means of elutriation. In the book under review, the authors consider each of these in turn, and describe the methods applicable to each type of problem. The lucid and readable descriptions are such that the methods ought to be easily understood, even by those whose mathematical equipment is very meagre. The few more recondite methods which have been introduced are generally alternative to simpler explanations and need not concern the average student. Numerous examples illustrative of those types which occur in works' practice are included, while several useful tables of data are appended. The book will undoubtedly be found to fill an awkward gap in ceramic literature, and should prove of great value and assistance to all serious workers and students. A.S.

Anlage, Einrichtung und Betrieb einer Porzellanfabrik.

By Oskar Georgi. (Coburg, 1919.)

This little book, of approximately 160 pages, deals, as its title indicates, with the planning-out, equipment and management of a porcelain works engaged in the manufacture of table wares in particular. The author states in the preface that he would not have undertaken this work, had anything similar already been published. As might be expected, the subject is dealt with from the commercial rather than from the technical point of view. The book opens with a short historical sketch of the development of German industry and the part played therein by the various geographical, geological and economic factors. With the aid of a sketch and plan, the most advantageous method of planning out a factory is illustrated. This is followed by sample estimates to indicate the method of arriving at the cost of the buildings, kilns, plant, etc., the whole outlay being based on the requirements of a 3-kiln works, employing about 150 persons. The questions of capitalisation, and estimation of probable net profits to be anticipated, are then considered. For the purposes of management, the concern is grouped into (1) a technical, and (2) a commercial department. With regard to personel, the author takes as his dictum : "Men for the work" and not "Work for the men."

Methods of book-keeping, accounting and costing are discussed in some detail.

Several short articles (reprints) dealing with costing, grading, kiln-lists and monthly balance sheets, etc., are given as an appendix.

On the whole, a praiseworthy attempt has been made to treat a by no means simple matter as briefly as possible. F.S.

CERAMIC SOCIETY.

STATEMENT OF ACCOUNT FOR SESSION 1921-22.

Income.

	£	s.	d.
Balance in hand Session 1920–1921 ..	376	12	9
Members' subscriptions ..	833	16	7
Firms' ,, ..	197	8	0
Students' ,, ..	3	10	0
Advertisement Dept. ..	331	15	0
Donations from British E'ware. Manufacturers' Association	100	0	0
Transactions sold	326	13	1
Blocks sold	4	4	0
Postages paid	4	16	2
Sundries		16	5
Bank Interest	7	11	7
Balance in hand from Swedish trip used up in preliminary expenses of trip (in various contra items)	19	3	10
	£2206	7	5

Expenditure.

	£	s.	d.
Printing Transactions ..	1175	9	6
Blocks	32	0	1
Abstracting	55	9	0
Journals	85	19	4
Binding	5	7	0
Expenses of Meetings ..	86	16	4
Reporting	5	2	0
Postages	136	1	7
Printing and Stationery ..	151	13	4
Insurance	1	5	0
Bank Charges	5	6	6
Cheque Books	1	0	0
Unpresented Cheque, 1920/21	2	5	0
10% Commission on Advt. A/c.	30	4	0
Bourner Bullock & Co. ..	3	3	0
Addressall Machine	32	4	7
Gov. of School of Science for services of typists ..	50	0	0
F. S. Worthington, Hon. Treasurer. Honor: ..	50	0	0
Miss Hulme ,, ..	5	0	0
Miss Lycett ,, ...	2	0	0
Income Tax	11	14	0
Sundries	13	14	7
Balance in hand	264	12	7
	£2206	7	5

As against the Balance of £264 12s. 7d,, there are estimated accounts owing for £220 to complete the Statement of Account for Session 1921/1922.

Audited and found correct, November 13th, 1922.

Signed by F. TURNER,
C. E. RAMSDEN.

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ABSTRACTS.

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INTRODUCTION.

THE following are abstracts from papers bearing upon the clay, refractories, and glass industries in the more important foreign journals as well as those of our own country. The abstracts are arranged roughly in eight main classes. The groups are constantly overlapping, and, to avoid repetition, a copious index is appended. This will enable any reference to be quickly found. Most of the journals quoted are permanently filed so that the full papers may usually be consulted by members of the Society. Full translations of any of the foreign papers can be obtained at a small charge. As a rule the abstractor indicates the "subject title" of those articles which, in his opinion, contain either no original matter, or matter not suitable for abstraction. These abstracts were made possible by a grant from the Joint Committee of Allied Pottery Manufacturers, and were compiled by Mr. F. SALT (with the exception of a few initialled).

The following particulars respecting patents may be of use to members:—

Country	Address	Cost
Britain ..	Patent Office, London	One Shilling (extra postage outside United Kingdom)
United States	Patent Office, Washington ..	Five cents
France ..	L'Imprimerie Nationale, 87, Rue Vielle du Temple, Paris	One franc
Germany ..	Patent Office, Berlin	
Austria ..	Buchhandlung Lehmann und Wenzel, Wien I, Kärntnerstrasse, 30	One krone
Denmark ..	Patent Office, Copenhagen ..	One krone
Norway ..	Patent Office, Christiania ..	One krone
Sweden ..	Patent Office, Stockholm ..	One krone
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Japan ..	— — Tokyo	Price not stated
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In ordering a copy of a patent, the number of the patent and year of the patent, the name of the patentee and the subject of the invention should be stated.

Titles of Journals Abstracted, with Abbreviations.

Allg. Tonind. Ztg... "Allgemeine Tonindustrie Zeitung" (Czecho-Slovakia)
Amer. J. Sci..... "American Journal of Science" (American)
Amer. Min..... "American Mineralogist" (American)
Analyst..... "The Analyst" (British)
Ber. D. K. Ges. .. "Berichte der Deutschen Keramischen Gesellschaft" (German)
Blast Fur..... "Blast Furnace & Steel Plant" (American)
Brennstoff..... "Brennstoff-Chemie" (German)
Brick..... "Brick & Clay Record" (American)
Brick Pot. Tr. J..... "Brick & Pottery Trades Journal" (British)
Brit. Claywr..... "British Clayworker" (British)
Bull. Imp. Inst..... "Bulletin of the Imperial Institute" (British)
Can. Chem. Met..... "Canadian Chemistry & Metallurgy" (British)

Eng. News..... "Cement & Engineering News" (American)
Cer..... "La Céramique" (French)
Ceramist..... "The Ceramist" (American)
Cer. Vet..... "La Ceramica ed il Vetro" (Italian)
Chem. Age..... "Chemical Age" (British)
Chem. Appar..... "Chemische Apparatur" (German)
Chem. Met. Eng... "Chemical & Metallurgical Engineering" (American)
Chem. News..... "Chemical News" (British)
Chem. Tr. J. "Chemical Trade Journal & Chemical Engineer" (British)
Chem. Zentr..... "Chemisches Zentralblatt" (German)
Chim. Ind..... "Chimie et Industrie" (French)
China Rev..... "China & Clay Trade Review" (British)
Claywr..... "Clayworker" (American)
Corr. Cer..... "Corriere dei Ceramisti" (Italian)
Deut. Töp. Zieg. Ztg. "Deutsche Töpfer und Ziegler-Zeitung" (German)
Diamant..... "Diamant und Glas-Industrie Zeitung" (German)
Econ. Geol..... "Economic Geology" (British)
Eng. Ind. Man..... "Engineering and Industrial Management" (British)
Faenza..... "Faenza" (Italian)
Feuerung..... "Feuerungstechnik" (German)
Gas J..... "The Gas Journal" (British)
Gas World..... "Gas World" (British)
Gazz. Chim. Ital..... "Gazzetta Chimica Italiana" (Italian)
Giorn. Chim..... "Giornale di Chimica industriale ed applicata(Italian)
Glashütte..... "Glashütte" (German)
Glas-Ind..... "Die Glasindustrie" (German)
Glass Ind..... "The Glass Industry" (American)
Ind. Chim..... "L'Industrie Chimique" (French)
J. Amer. Cer. Soc. "Journal of the American Ceramic Society" (American)
J. Amer. Chem. Soc. "Journal of the American Chemical Society" (American)
J. Chem. Soc..... "Journal of the Chemical Society" (British)
J. Ind. Eng. Chem. "Journal of Industrial & Engineering Chemistry"(Amer.)
J. Soc. Chem. Ind. "Journal of the Society of Chemical Industry" (British)
J. Soc. Glass Tech. "Journal of the Society of Glass Technology" (British)
Kalk Schm.-Ztg..... "Kalk-, Gips-und Schamotte-Zeitung" (German)
Ker. Rund..... "Keramische Rundschau" (German)
Met. Erz..... "Metall und Erz" (German)
Min. Met..... "Mining and Metallurgy" (American)
Nature..... "Nature" (British)
Pat. J..... "The Illustrated Official Journal (Patents)" (British)
Porz. Glas..... "Die Porzellan und Glashandlung" (German)
Pot. Gaz..... "Pottery Gazette" (British)
Pot. Glass Rec..... "Pottery and Glass Record" (American)
Prod. Chim..... "La Revue des Produits Chimiques" (French)
Quarry.... "The Quarry & Surveyors' & Contractors' Journal (British)
Rev. Mat. Constr. Trav. Pub. "Revue des Matériaux de Construction et de Travaux Publics" .....(French)
Rock Prod..... "Rock Products" (American)
Sprech..... "Sprechsaal" (German)
Stahl Eis..... "Stahl und Eisen" (German)
Tonind. Ztg..... "Tonindustrie Zeitung" (German)
Tonwar. Ofen Ztg..... "Tonwaren Ofen-und Töpfer-Zeitung" (German)
TRANS..... "Transactions of the Ceramic Society" (British)
Trans. Faraday Soc..... "Transactions of the Faraday Society" (British)
Verre..... "Le Verre" (Belgian)
Zeits. angew. Chem..... "Zeitschrift für angewandte Chemie" (German)

*** The first number represents the number of the volume, the last the year of publication, and intermediate numbers the page or pages where the subject is discussed.

Abstracts.

1.—RAW MATERIALS: GENERAL.

RAW MATERIALS: OCCURRENCE, PREPARATION, ETC.

GRAPHITE IN NEW ZEALAND.—P. G. Morgan (*N.Z. J. Sc. & Tech.*, **2**, 198, 1919). Graphite is widely distributed throughout New Zealand. It occurs in deposits of various sizes in the marbles, gneisses and schists of western Otago, in the mica-schists of Central Otago, in the greywackes and argillites of western Canterbury, and in the schists, argillites and marbles of Nelson and Marlborough. Graphite is also found in the greywackes and argillites and volcanic rocks (Mount Egmont) of the North Island. The Otago and Nelson rocks are of Palaeozoic age; the greywackes and argillites of western Canterbury, eastern Westland and Wellington are probably of early Mesozoic age; and the volcanic rocks are of Tertiary, or in the case of Mount Egmont, of post-Tertiary age. The available information concerning 34 occurrences is given in brief form. The numerous records of graphite occurrences in New Zealand indicate a probability of workable deposits being found if search is made, especially in north-west Nelson.

THE AMERICAN MAGNESITE INDUSTRY IN 1920.—(*Chem. Met. Eng.*, **24**, 744, 1921). The production of magnesite in the U.S. increased by 94% in 1920 over 1919. The entire out-put (303,767 short tons) was made by the States of California and Washington. The quantity imported during 1920 was 43,154 long tons, mainly from Italy and Canada.

PRODUCTION OF BAUXITE IN 1920.—(*Chem. Met. Eng.* **25**, 16, 1921.) According to figures collected by the U.S. Geological Survey, 521,308 long tons of bauxite were produced, and 42,895 long tons imported in the U.S. in 1920, as compared with 376,566 and 6,082 long tons respectively in 1919.

KAOLIN IN NORTH CAROLINA, WITH A BRIEF NOTE ON HYDRO-MICA.—W. S. Bayley (*Econ. Geology*, **15**, 236, 1920). Kaolins may exist as veins, where they are derived from pegmatites or other vein-like masses, or as blanket deposits, where they owe their origin to broad expanses of igneous or metamorphic rocks. In N. Carolina, both types are present, but all, so far as is known, occur west of the "fall line." The first type is found in the mountain districts, the second on the Piedmont plateau. The following analyses of N. Carolina kaolins are given:—

Kaolin	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Na_2O K_2O	H_2O	Total
A. ..	62·40	26·51	1·14	·57	·01	·98	8·80	100·66
B. ..	53·10	33·06	1·18	·38	·08	·83	11·32	99·95
C. ..	46·41	37·76	·70	—	·09	·72	13·46	100·28

Evidence is cited to show that the mountain kaolins were produced by the decomposition of felspar, brought about by the action of percolating ground water travelling downward from the surface and carrying with it dissolved CO_2 and organic matter. When changing to kaolin, orthoclase loses SiO_2 and K_2O and adds H_2O.

or in chemical symbols: $2KAlSi_3O_8 - 4SiO_2 - K_2O + 2H_2O = H_4Al_2Si_2O_9$. The alteration of orthoclase may be effected by pure water, with the production of potash, colloidal aluminous silicates, colloidal silica, and kaolinite. Upon hydrolysis by water, the felspar yields KOH and an unstable silicate, which readily parts with some of its silica and is converted into kaolinite thus: $KAlSi_3O_8 + H_2O = KOH + HAlSi_3O_8$; $2HAlSi_3O_8 + H_2O = H_4Al_2Si_2O_9 + 4SiO_2$. The process is hastened by the addition of H_2SO_4 or CO_2. When CO_2 is present, as in freshly fallen rain, and in water which has passed through decomposing matter, the process may be indicated by the equation: $2KAlSi_3O_8 + 2H_2O + CO_2 = H_4Al_2Si_2O_9 + K_2CO_3 + 4SiO_2$. The kaolinization processes are described in some detail.

Hydromica. The muscovite changes so slowly that it may be picked by hand from the kaolin. Near the surface, however, in many places the mica is more or less altered and at some localities it has lost its characteristic features. Under the microscope, between crossed nicols, the mica is discovered to be much less strongly doubly refracting than fresh muscovite. The writer thinks it probable that the altered mass is an aggregate of tiny decomposition products embedded in a matrix containing a residual of muscovite rather than a definite mineral. It appears to be one of the "hydromicas" so frequently described as occurring in clays. An analysis of a particularly good specimen gave the following result:

SiO_2	Al_2O_3	Fe_2O_3	FeO	MgO	CaO	Na_2O	K_2O	H_2O	TiO_2	Moist.	Total
40·79	29·98	8·07	2·48	2·71	·45	·38	3·47	9·34	1·28	1·20	100·15

Regarded as a mixture, the mineral composition of the material, calculated from the analysis on the assumption that the Fe_2O_3 is in limonite, the TiO_2 in rutile, and the FeO in a ferruginous serpentine, may be: kaolinite 43·34, muscovite 34·04, serpentine 11·41, quartz or other form of SiO_2 1·08, limonite 8·90, rutile 1·28, total 100·05. These figures indicate the probable composition of most of the hydromicas occurring in kaolin, and show that this substance differs from muscovite in the presence of much less K_2O and possibly Al_2O_3 and of much more H_2O.

With regard to the distribution of kaolin in the veins, it is pointed out that, in the deposits situated well up on the slopes, the depth at which profitable mining is no longer possible is at about 95 ft. from the exposed surface. The purer kaolin is found at about water-level, and above this kaolinization is practically complete. Since the level of the ground-water is nearer the surface on plains than in deposits high up on slopes, the latter are apt to be minable at greater depths than the former. In general, a dike is richer in kaolin near its foot-wall than near its hanging. This again suggests alteration by downward-percolating water. The hanging wall, especially if composed of schists, protects to some extent against the downward-flowing water, whereas at the foot-wall the water flow is more abundant.

REFRACTORY SUBSTANCES.—Osmosis Co. Ltd., D. Laurie, and W. R. Ormandy (*Pat. J.*, 1,685, 1921). No. 159,737, Jan. 22, 1920. Refractory articles are made by firing specially purified china clay without a flux at temperatures below 1,500°C. The clay is purified by methods set forth in Specifications 2,379/11, 3,364/11, 27,930/11, 27,931/11, 28,185/11 and 14,235/12. For example, it is made into a slip with a dilute electrolyte such as caustic soda or sodium silicate, allowed to stand for about 24 hours and is either subjected to electro-osmosis, or precipitated by a coagulating agent, such as aluminium sulphate and reconverted to the sol condition by treatment with an alkali. The purified clay is made into a slip, to which a grog made of vitrified china clay may be added to minimize contraction on firing.

TRANSPORTING FULLER'S EARTH, ETC.—L. G. Hill (*Pat. J.*, 1,689, 1921). No. 161,419, Mar. 8, 1920. Fuller's earth, ground argillaceous rocks or marls, or other finely-divided material or coarsely-powdered or granular materials liable to produce dust, are mixed with a solution of sodium silicate or other binding agent soluble in water and dried to form lumps that are dustless in transport. The powder, etc., is reformed by dissolving out the binder.

ZIRCONIUM AS DEOXIDIZER IN CAST IRON.—(*Foundry*, **48**, 878, 1920). In making tests with ferrozirconium, an alloy containing 30·6% zirconium was added. The metal behaved nicely in melting and indicated a purifying action ; the slag came up and collected for easy removal. Larger percentages gave more trouble and chilled the metal considerably, so that it was difficult to pour successfully. Undoubtedly, the alloy will do better service in steel than in cast iron. Two sets of tests were made, one with a gray iron mixture and the other with car wheel scrap, thus obtaining results for gray and white iron :—

Gray Iron Mixture.
Pig 60%, gray scrap 40%. Average of 3 bars.

Breaking Strength. Pounds.	Deflection. inch.	Zirconium added. per cent.
2,700	0·10	none
2,920	0·11	0·05
2,900	0·11	0·10
3·050	0·11	0·15

White Iron Mixture.
Scrap car wheels 60%, white iron scrap 40%.

Breaking Strength. Pounds.	Deflection. inch.	Zirconium added per cent.
2,640	0·10	none
2,790	0·10	0·05
2,880	0·11	0·10
2,940	0·11	0·15

As the usual element addition for deoxidation purposes is 0·10 per cent., it will be noticed that the strength increase is 6 and 9 per cent respectively.

THE TECHNICAL ANALYSIS OF AUCKLAND CLAYS.—A. B. Jameson (*N.Z. J. Sc. and Tech.*, **2**, 209, 1919). In this paper an attempt is made "to indicate the nature of the problems and to suggest avenues of further research, rather than to supply complete and definite information on any special part of the subject." The clay beds of Auckland, which extend in an almost unbroken sheet from Riverhead, around the shores of Waitemata Harbour, to Avondale and New Lynn, are regularly stratified, the consistency of the strata varying from a very plastic to a fine sandy nature. In all localities there occurs a band of pure white water-worn pumice interstratified with the deeper clay beds. It has been shown by microscopical examination that the Auckland clays are connected etiologically with rhyolites and pumice, and not with crystallised felspar and mica. Their stratigraphy indicates that they have been water-borne by the Waikato river. Since solfataric action on rhyolite pumice is capable of producing a pure form of kaolin, the author suggests that these clays owe their origin to the weathering of pumice in the Waikato drainage area. Zschokhe's method of "combined analysis" was selected for analysing the clays, as being the best suited to give useful information to the manufacturer. The clay is elutriated into two fractions—*A*, clay fraction, and *B*, sand fraction—which are then separately extracted with 10 per cent. HCl.

A.	(*a*) Insoluble in HCl, treated with H_2SO_4	(*c*) Insoluble in H_2SO_4:	Quartz, felspar, mica, etc., determined by microscopic investigation.
		(*d*) Soluble in H_2SO_4:	Clay, reckoned by difference.
	(*b*) Soluble in HCl ..		Estimated by difference. $CaCO_3$, $CaSO_4$, $MgCO_3$, $MgSO_4$, and FeO, determined by microscopic investigation.
B.	(*e*) Insoluble in HCl	..	Coarse grains of (*c*)
	(*f*) Soluble in HCl	..	Estimated by difference—coarse grains of (*b*)

A modification of the table gives the following :—

A, "clay fraction"	Actual clay	(*d*)
	Fine sand	(*c*)
	Fine carbonates, etc.—*i.e.*, flux ..	(*b*)
B, "sand fraction"	Coarse sand, etc.	(*e*)
	Coarse carbonates, etc.	(*f*)

The composition of the clay is thus stated in such a way as to suggest to the manufacturer the means of modifying that composition. By reblending the clay and sand fractions into mixtures of known composition, an attempt was made to show how the firing properties of the clays could be interpreted from the analytical data. Two properties only were selected for observation : (1) The shrinkage of moulded samples on drying and on firing respectively, and (2) the porosity of the fired ware. The clay samples were separated by means of the Schöne elutriator into the "clay" and "sand" fractions, and these were then reblended in various proportions. Samples of the synthetic products were then fired in a Seger gas furnace, the temperature in all cases being raised to cone 14 (about 1,410°C.). The results for sample No. 1 were as follows :—

Clay Fraction (per cent.)	Sand Fraction (per cent.)	Total Tempering material* per cent.)	Shrinkage (Percentage of Original Volume)		Porosity (Percentage of Total Volume)
			Air	Fire	
75	25	35·1	20·5	28·5	6·3
45	55	61·1	17·0	11·5	30·5
30	70	74·0	22·0	0·0	34·0

* "Tempering Material" = all material in mixture other than "actual clay (*d*)."

It is seen that the fire shrinkage is approximately inversely proportional to the amount of tempering-material present. (The reason for the air shrinkage increasing again above 60% of tempering-material has not yet been investigated). The results for sample No. 7 show the same regular falling-off both in air and fire shrinkage as the proportion of tempering-material increases. In the case of sample No. 3, on the other hand, the shrinkage in the fire increases steadily as the proportion of its own tempering constituents is increased. This unusual result is explained in part by reference to the analytical results (below), for the tempering-material is seen to include some 4·6% of alkali earths and iron, which act as fluxes. The analysis thus indicates important information to the manufacturer, who is accustomed to regard an increase of "sand" in his clay as tending to reduce shrinkage in the fire. Much obviously depends on the nature of the sand.

RESULTS OF COMBINED ANALYSES.

	Sample No. 1	Sample No. 3	Sample No. 7	Sample No. 14
(*d*) Actual Clay ..	65·6	4·2	24·4	44·1
(*c*) Fine Sand ..	10·2	2·7	60·0	24·2
	32·6	90·1	76·3	44·8
(*e*) Coarse Sand ..	22·4	87·4	16·3	20·6
(*b*) Fine Fluxes ..	trace	1·6	trace	8·0
		4·6		9·2
(*f*) Coarse Fluxes ..	nil	3·0	nil	1·2

Ultimate Analyses and Notes :—

Sample No. 1—A large proportion of isotropic glass was distinguished in (*c*) and (*e*) ; otherwise (*e*) was chiefly quartz grains.

Sample No. 3.—Whole sample : Fe_2O_3 10·0% ; CaO 1·6% ; MgO trace. In (*b*) and (*f*) Fe_2O_3=1·1%.

Sample No. 7.—(*c*) and (*e*) chiefly glass. A remarkably strong clay for the relatively low value of (*d*).

Sample No. 14.—Volumetric estimation of Fe in (*b*) and (*f*) gave Fe 2·5%. CaO and MgO not determined.

As the result of investigations, it was shown that the fine rhyolite sand occurring in these clays acts as a flux and not as a tempering-material in the fire. Various fields for further investigation are indicated at the close of the paper.

THE WATER SMOKING OF CLAYS.—R. F. Geller (*J. Am. Cer. Soc.*, **4**, 375, 1921). The water smoking behaviours of two plastic clays, one shale, and one fireclay, were studied by heating 4-in. cubes at different rates, two thermo-elements being buried in the brick and two others placed against the outer surface. The conclusions drawn are as follows :—To save time in water smoking, the ware should be previously dried not far from 100°C., good circulation should be provided in the kiln, and the temp. of the interior of the product should not lag appreciably behind that of the kiln. It should be possible to water smoke heavy clay products in 15 hours with a heating rate of 20°C. per hour.

THE ABSORPTION OF SODIUM HYDROXIDE BY KAOLINS.—R. F. Geller and D. R. Caldwell (*J. Am. Cer. Soc.*, **4**, 468, 1921). The amounts of sodium hydroxide completely absorbed by N. Carolina, Georgia and Florida kaolins, without showing the presence of free alkali sufficient to colour phenolphthalein are, respectively : 0·125% ; between 0·100 and 0·125% ; and between 0·225% and 0·250% of the dry weight of the clay. The absorption appears to be largely independent of time but increases with temperature. The experimental data can be expressed by the Freundlich adsorption isotherm, thus indicating that the absorption process belongs to the category of adsorption phenomena.

THE RELATION BETWEEN THE FINENESS AND OTHER PROPERTIES OF CALCINED GYPSUM.—W. E. Emley and F. C. Welch (*J. Am. Cer. Soc.* **4**, 301, 1921). The normal consistency was measured by the Southard viscosimeter, the time of set by the Vicat needle, and the plasticity by spreading upon a porous porcelain plate. *Conclusions* :—(1) Normal consistency is obtained with less water the coarser the calcined gypsum. (2) The finer the material, the shorter the time of set. (3) The finer the calcined gypsum, the stronger the set material up to a fineness beyond size 6 (A.S.T.M. spec.),

after which increase in fineness is accompanied by decrease in strength. (4) The finer the calcined gypsum the more sand it will carry.

NOTE ON THE EFFECTS OF FIRING TEMPERATURE ON THE STRENGTH OF FIRE-CLAY AND STONEWARE BODIES.—H. G. Schurecht (*J. Am. Cer. Soc.*, **4**, 366, 1921). The cross breaking strengths, porosities and shrinkages of fire-clay and stoneware bodies were determined after firing to different temperatures. It was found that, with one exception, maximum strength was developed by firing to cone 8, even when porosity and shrinkage data showed the bodies to be over or under fired at this temp. The cause of weakening above cone 8 may be due to the formation of sillimanite. Bodies which develop maximum shrinkage and minimum porosity at cone 8 have a greater ratio of fired strength to dry strength when fired to cone 8 than those which are under or overfired at this temp.

THE "WHY" OF AGEING CLAY.—H. Spurrier (*J. Am. Cer. Soc.*, **4**, 113, 1921). The evolution of CO_2 was found to continue for over 34 days after pugging and, like the change of plasticity, to proceed more rapidly between 80° and 90°F. than below 60°. The effect of replacing water by non-aqueous liquids was to inhibit the development of plasticity altogether. The addition of a dilute solution of H_2O_2 produced a pronounced increase in viscosity and also stimulated the growth of alga and the consequent evolution of both CO and CO_2. It seems probable therefore, that the change of plasticity of clays with time is due, in some way, to the growth of algae. This theory would explain all the effects found. The ratio of the amounts of Al_2O_3 and SiO_2 dissolved by caustic potash was found, for three clays tested, to decrease rapidly with diminishing plasticity; it might well be used, therefore, as a quantitative measure of plasticity.

NOTE ON THE EFFECT OF TIME ON THE DRYING SHRINKAGE OF CLAYS.—R. F. Geller (*J. Am. Cer. Soc.*, **4**, 282, 1921). The drying shrinkage of clays was studied to determine how quickly different types can be dried and to note whether or not the time of drying influences the amouut of shrinkage. Three shales, two ball clays and one fire-clay were tested and the following conclusions reached: (*a*) drying time depends largely on water content; (*b*) the structure of the clay is an important factor; (*c*) the amount of total shrinkage is proportional to the water content; (*d*) the amount of total shrinkage is not influenced by the rapidity of drying.

A STUDY OF THE HEATING AND COOLING CURVES OF JAPANESE KAOLINITE.—S. Satoh (*J. Am. Cer. Soc.*, **4**, 182, 1921). On heating Japanese kaolinite at 100° to 1,400°C. for 3 to 4 hours, it was found that the loss of weight on ignition occurred chiefly between 400° and 600°, the rate of increase per degree reaching a maximum at about 460°C. Changes of microstructure were observed at 600°, 900–1,000°, 1,250-1,300° and at 1,400°C., when sillimanite began to develop. A differential method was used with quartz sand as the comparison substance. In addition to the known reactions: (1) an endothermic from 450° to 700°, and (2) an exothermic near 950°, (3) an exothermic change between 1,200 and 1,300° was noticed, and it was observed that the endothermic reaction seems to include two periods of heat absorption, (1*a*) 450 to 650° and (1*b*) 650 to 700°. In explanation, the author suggests that 1*a* is due to dehydration, 1*b* to dissociation of kaolinite into free alumina and free silica, 2 to a polymerisation of the alumina, and 3 to the formation of amorphous sillimanite. In the discussion, E. W. Washburn calls attention to the fact that the author has neglected the endothermic reaction of quartz at 575°C. and suggests that some of his conclusions are therefore erroneous. In alumina, obtained from the nitrate, hydroxide and sulphate by calcination, exothermic reactions, which are ascribed by the author to polymerisation of alumina, occur at 800° to 900° and 1,100 to 1,200°, instead of at 950° and 1,250° as in the case of kaolinite.

EXPERIMENTS IN DEAD-BURNING DOLOMITE AND MAGNESITE.—H. G. Schurecht (*J. Am. Cer. Soc.*, **4**, 127, 1921). Dolomite is

difficult to dead-burn, because the absorption of moisture from the air produces a gradual slacking, due, probably to the dydration of lime and various lime compounds, and this tends to cause disintegration. With all the fluxes tried, 100-mesh raw material gave greater resistance to slacking than 8-mesh size. This resistance diminished, however, with increasing temp. of calcining by an amount which seems to depend on the silica and alumina content of the flux, being greatest for basic open-hearth slag and kaolin, less for flue dust and iron ore, and least for roll scale. The stability of calcined dolomite also varied with the proportions of flux used, being greater, as a rule, for smaller proportions. The shrinkage and porosity curves for mixtures containing flue dust, iron ore or roll scale are very similar. The higher the proportion of flux, the lower the temp. required to give maximum shrinkage and minimum porosity. Kaolin and basic open hearth slag behaved peculiarly, in that vitrification depended more on the burning temperature than on the proportion of flux used. It was found that ageing of the wet calcined material was necessary to prevent cracking of the bricks upon drying. With 5% $MgCl_2$ as binder, comparatively strong bricks were obtained. High shrinkage on firing caused excessive cracking, but the bricks were extremely dense and did not disintegrate until after 4 to 6 months. Unfired tar-bonded bricks were made with sufficient strength to stand shipping and with a storage life of about 4 months. Fired tar-bonded bricks showed less shrinkage and cracking than similar bricks made with water. If dipped in tar to protect them from moisture, such bricks will last 5 or 6 months before disintegration. It is possible, then, to make dolomite bricks with a storage life long enough to allow shipping and placing in furnaces.

Unlike dolomite, magnesite showed less slacking effect the higher the temp. of burning. Roll scale gave greater stability than iron ore, probably because of its lower silica content. The product was comparatively porous and with low shrinkage, even with high proportions of roll-scale.

II—MANUFACTURING PROCESSES:

GENERAL:

THE PREPARATION OF DOLOMITE-TAR MIXTURES IN BASIC STEEL PRACTICE.—M. Backheuer (*Stahl Eis.*, **41**, 954, 1921). On the basis of practical experience, the preparation and use of dolomite-tar mixtures for converters are described, and a method is indicated for burning the plugs, rendering them free from cracks, and giving greater durability to the "packing" The quality of the mixture is affected both by the chemical composition and the physical condition of the ground dolomite. Lightly burned dolomite, with a low percentage loss on ignition (2 to 4%) is the best for the purpose, since highly sintered material will not absorb the tar so well. The mixture must be prepared in a warm condition, so that the tar does not become thick. The temperature of the tar should not be below 80°, since the quality of the finished product depends mainly upon the extent to which the tar is absorbed by the dolomite. For converter linings, the shrunk dolomite should be ground so as to consist of from 35 to 40% of flour, 30% fine and 30% coarse grains. This must be thoroughly mixed with 8 to 10% of tar in the edge mill. Ground pieces of old linings may also be added to the extent of 20% in the lower portion and up to 30% in the upper or neck section. When, as is often the case, pieces break away or peel off from a new lining after the first burning, this is generally due to the use of a too viscous tar or imperfectly shrunk dolomite. The finished mixture must not be worked into the converter in a cold state, but at about the temperature of the hand. An important factor in practice, is the durability of the "packing" used to fill up the circular space between the plug and the lining of the lower part of the converter body. In preparing this packing material, great care should be taken, so that, after

being poured in, both dolomite and tar are equally distributed throughout the mass, that is to say, there must be no accumulation of dolomite in one place or of tar in another. A mixture, which gives satisfactory results, is prepared as follows : The shrunk dolomite is ground fine on a clean edge mill, so as to consist of about 60% powder, 30% fine and 10% coarse grain. This powdered dolomite is added, with constant stirring, and one shovelful at a time, to the requisite quantity of tar, which, at the commencement, must have a temperature of at least 80°. Both the mixing apparatus and the tar must be kept warm throughout the operation. The finished mixture contains from 20 to 25% of tar. It must be perfectly homogeneous ; that is, it must not be possible for the dolomite to settle in places. The dolomite powder must, so to speak, be held in suspension by the tar. For converter bottoms (plugs), the shrunk dolomite is often ground finer than for the converter walls. It consists of about 45 to 50% powder, 25% fine and 25% coarse grain. The mixture, containing about 12% tar, requires a more thorough mixing in the edge mill than that for the converter walls. It is tamped in a warm condition, so that it is not broken up by the iron rods which pierce it. The use of viscous tar often causes pieces to break away from converter bottoms.

REFRACTORY BRICKS.—O. Rebuffat (*Pat. J.*, 1,685, 1921). No. 159,865, Jan. 5, 1921. Bricks, etc., composed chiefly of silica are made from a mixture containing a small proportion, *e.g.*, 0.45%, of phosphoric, tungstic, molybdic, boric or other acid stable at high temperatures, or a salt of such acid. The bricks are fired at a temperature of 1,300–1350°C.. to convert the silica into modifications of low specific gravity, such as tridymite.

MAKING BRICKS, POTTERY, ETC.—C. W. Wallace (*Pat. J.*, 1,692, 1921). No. 162,483, Mar. 11, 1920. Bricks, pottery, and artificial stone products are obtained from clayey material (*e.g.*, the white clayey material found near Molo, in British East Africa), by introducing pressed, turned, or otherwise shaped pieces of the clay directly into the flames of a furnace, heating throughout, and effecting sudden cooling by plunging into water.

PLASTER OF PARIS.—W. M. Brothers (*Pat. J.*, 1,695, 1921). No. 163,468, Feb. 18, 1920. Plaster of Paris is manufactured in a continuous manner by feeding powdered gypsum or old plaster moulds through a closed vessel under pressure, in the presence of dry steam at 380–420°F. generated only from the raw material itself.

CHEMICAL STONEWARE MANUFACTURE.—C. H. Jones (*Chem. Met. Eng.*, **25,** 289, 1921). The production of chemical stoneware involves ceramic problems differing from other wares for various uses in chemical plants. The article has numerous illustrations and deals with the following factors : preparing the body, ageing the clay, forming the pieces, drying and burning, finishing the fired ware, and plant control.

GLIMPSES OF OHIO CERAMIC INDUSTRIES.—C. H. Jones (*Chem. Met. Eng.*, **25,** 562, 1921). Ohio is the largest producer of ceramic ware in the U.S.A. The State has approximately 550 different clay-working plants with an average production of $96,000 each annually. The work of the Bureau of Mines and State University in furthering clay-working industries by scientific research and training is discussed. Stoneware plants at Akron and near Roseville are described and their methods of working illustrated.

GLIMPSES OF OHIO CERAMIC INDUSTRIES—II.—C. H. Jones (*Chem. Met. Eng.*, **25,** 619, 1921). This article is devoted to an account of the Crooksville China Co., in southern Ohio, which manufactures tableware. Sub-headings include : Saggars ; Preparing the Slip ; Materials for Pottery bodies ; Scientific study of clay body composition ; Alkali treatment of casting slip and constitution of glazes.

SLAG BRICKS.—R. Milner and T. Robinson (*Pat. J.*, 1,695, 1921). No. 163,569, Apr. 13, 1920. Blast-furnace slag is ground and mixed with not more than 20% of clay and a sufficient quantity of ground carbon fuel to form a self-binding mixture, which is moulded into the required shapes, dried, and then fired in kilns. A suitable mixture is :—70–85% slag, 5–20% clay and 5–15% fuel.

MAGNESIA BODIES.—A. Berge (*Sprech.*, **53,** 1—3, 1920). A description of various tests carried out with the object of determining possible means of (1) utilising magnesia, (2) effecting fuel economy by reducing the firing temperature. Mixtures of magnesia and silica, magnesia and felspar, and magnesia, felspar and alumina were first tried, to study the effect of magnesia on the three substances. It was found that mixtures of 1 mol. SiO_2 with 1 mol. MgO, and of 2 mol. SiO_2 with 1 mol. MgO retained the character of porous stone ware at a temperature of cone 12, and were therefore unsuitable, without the addition of other fluxes, for firing at low temperatures. A mixture of felspar and magnesia—$3SiO_2$: 0·5 Al_2O_3: $\begin{cases} 0{\cdot}5\ K_2O \\ 0{\cdot}5\ MgO \end{cases}$—fused at cone 4 to a white mass, like porcelain, and at cone 010 resembled a hard stoneware body. The magnesia content of this mixture was then increased from 2·4 SiO_2: 0·4 Al_2O_3: $\begin{cases} 0{\cdot}6\ MgO \\ 0{\cdot}4\ K_2O \end{cases}$ to (1) 0·6 SiO_2 : 0·1 Al_2O_3: $\begin{cases} 0{\cdot}9\ MgO \\ 0{\cdot}1\ K_2O \end{cases}$ the burning temperature rising steadily to cone 12, at which temperature mixture 1, consising of 40 parts magnesia and 60 felspar, gave a pure white, highly transparent porcelain with an oily fracture. A mixture of the form (2) 1·2 SiO_2: 0·2 Al_2O_3: $\begin{cases} 0{\cdot}8\ MgO \\ 0{\cdot}2\ K_2O \end{cases}$ containing about 23 parts magnesia and 77 parts felspar, was converted to porcelain at cone 7, and at cone 9 showed signs of fusing on the surface, which appeared to have been glazed. A mixture of 15 parts magnesia and 85 parts felspar of the formula (3) 1·8 SiO_2 : 0·3 Al_2O_3: $\begin{cases} 0{\cdot}7\ MgO \\ 0{\cdot}3\ K_2O \end{cases}$ assumed the character of stoneware at cone 010 and of porcelain below cone 4. At cone 4 the tendency to self-glazing was observed. The same applied to a higher degree with the mixture (4) 2·4 SiO_2 : 0·4 Al_2O_3: $\begin{cases} 0{\cdot}6\ MgO \\ 0{\cdot}4\ K_2O \end{cases}$ (10% magnesia and 90% felspar). The burning temperature rises therefore with the magnesia content from cone 1 (with 7% MgO) to cone 12 (with 40% MgO). A body of 70 parts felspar and 30 magnesia, fired at cone 9, would satisfy the requirements of porcelain as regards colour, transparency and density, but would be difficult to cast. The shrinkage was practically normal. To improve the plasticity of the body, clay substance was added, the felspar at the same time being replaced by the cheaper quartz sand. In bodies No. 1 to 4, the RO was unchanged, and the alumina content increased by 0·1 mol., so that the mixture followed the formula (6) 0·8 SiO_2: 0·2 Al_2O_3: $\begin{cases} 0{\cdot}9\ MgO \\ 0{\cdot}1\ K_2O \end{cases}$ and consisted approximately of 30 parts magnesia, 23 parts alumina and 47 felspar. This body behaved similarly to body No. 1, giving a fine porcelain at cone 12. Shrinkage, however, was greater (28%) but on the other hand, the body was more suitable for moulding and casting. A body corresponding to (7) 1·4 SiO_2: 0·3 Al_2O_3: $\begin{cases} 0{\cdot}8\ Mg\ O \\ 0{\cdot}2\ K_2O \end{cases}$ (19 parts magnesia, 15 alumina and 66 felspar) gave a highly transparent porcelain at cone 7, but also exhibited the same high shrinkage (28%). Body No. 8 of the formula 2·6 SiO_2 : 0.4 Al_2O_3: $\begin{cases} 0{\cdot}7\ MgO \\ 0{\cdot}3\ K_2O \end{cases}$ fired to porcelain at cone 4. It contained about 13% magnesia, 12% alumina and 75% felspar. A body corresponding to (9) 3·4 SiO_2 : 0·5 Al_2O_3 : $\begin{cases} 0{\cdot}6\ MgO \\ 0{\cdot}4\ K_2O \end{cases}$ with about 9% magnesia, 10% alumina and 81% felspar, assumed a porcelain character a little above cone 1, and fused at cone 4.

The results of the numerous experiments are given in the following tables:

A. MAGNESIA—FELSPAR MIXTURES.

No.	Parts by Weight for		Firing Temp. for	
	Magnesia	Felspar	Stoneware	Porcelain
1	40	60	Cone 010	Cone 12
2	23	77	,, 4	,, 7
3	15	85	,, 010	,, 1
4	10	90	,, 010	,, 1
5	7	93	,, 010	,, 1

B. MAGNESIA—FELSPAR—KAOLIN MIXTURES.

No.	Parts			Firing Temp. for		Shrinkage
	Magnesia	Felspar	Kaolin	Stoneware	Porcelain	
6	30	47	23	Cone 8	Cone 12	28%
7	19	66	15	,, —	,, 7	28%
8	13	75	12	,, —	,, 4	—
9	9	81	10	—	,, 1	—

C. MAGNESIA—KAOLIN—QUARTZ MIXTURES.

No.	Parts				Firing Temp. for		Shrinkage
	Magnesia	Felspar	Kaolin	Quartz	Stoneware	Porcelain	
10	36	—	23	41	—	Cone 14	22%
11	23	—	15	62	Cone 14	—	—
12	14	—	9	77	,, 14	—	—
13	21	—	27	52	—	Cone 14	—
14	8	—	32	60	,, 4	,, 12	—

D. MAGNESIA—KAOLIN MIXTURES.

No.	Parts		Firing Temp. for		Shrinkage
	Magnesia	Kaolin	Stoneware	Porcelain	
15	30	70	Cone 4	Cone 12	—

E. MAGNESIA—FELSPAR—QUARTZ MIXTURES.

No.	Parts			Firing Temp. for		Shrinkage
	Magnesia	Felspar	Quartz	Stoneware	Porcelain	
16	24	36	40	—	Cone 9	—

F. MAGNESIA—FELSPAR—KAOLIN—QUARTZ MIXTURES.

No.	Parts				Firing Temp. for		Shrinkage
	Magnesia	Felspar	Kaolin	Quartz	Stoneware	Porcelain	
17	15	56	12	17	—	Cone 7	16%
18	10	34	8	48	—	,, 7	20%
19	7	24	6	63	Cone 4	,, 9	16%
20	6	20	4	70	,, 1	,, 10	—
21	5	16	4	75	—	,, 11	—
22	20	30	10	40	,, 8	,, 12	20%
23	10	20	10	60	,, 8	,, 12	10%
24	8	51	8	33	—	,, 4	—
25	6	36	6	52	—	,, 7	18%
26	6	56	7	31	,, 05	,, 1	—
27	5	40	5	50	,, 1	,, 4	—

The writer concludes that magnesia must be considered a very suitable material for reducing the burning temperature without seriously affecting the quality of the ware.

LIME-EARTHENWARE RECIPES. (*Sprech.* **54**, 195, 1921). A number of Lime-earthenware body and glaze recipes for the manufacture of cheap household utensils are given. The following are typical:

(1)

BODY.

Fat clay	21	21	18	15
Lean ,, ...	—	—	—	45
China ,, ...	15	21	13	5
Flint, calcined	40	31	37	20
Chalk	20	17	—	10
Dolomite marl	—	—	28	—
Felspar	—	4	—	5
Biscuit grog	4	6	4	—

GLAZE.

	Fritt.			*Mill-Mixing.*			
Felspar ..	41·5	16·0	30·0	Fritt	90	58	65
Sand ..	13·3	29·0	22·0	White lead ..	9	26	13
Red lead	18·5	—	—	Sand	—	—	11
Borax ..	16·5	29·0	30·0	Felspar ..	—	16	11
China clay	2·7	10·0	3·5				
Potash ..	1·0	—	4·5				
Chalk ..	6·5	15·0	11·0				

(2)

BODY.

White-firing earthenware clay (Wildstein)	30·3	30·3
China clay (Zettliz)	19·7	20·0
Quartz	30·0	25·0
Calcite	20·0	35·0

GLAZE.

	I. (leadless)	II.
Red-lead	—	107·980
Felspar	55·90	129·712
Borax	97·41	71·243
Soda	36·57	—
Boric acid	—	10·044
Calcite	30·00	10·750
China clay	70·71	10·504
Quartz	99·24	—

corresponding to the formulæ :—

(1) $\left.\begin{matrix}0{\cdot}1\ K_2O \\ 0{\cdot}6\ Na_2O \\ 0{\cdot}3\ CaO\end{matrix}\right\}$: $0{\cdot}373\ Al_2O_3$: $\left\{\begin{matrix}2{\cdot}8\ SiO_2 \\ 0{\cdot}51\ B_2O_3\end{matrix}\right.$

(2) $\left.\begin{matrix}0{\cdot}4736\ PbO \\ 0{\cdot}2324\ K_2O \\ 0{\cdot}1865\ Na_2O \\ 0{\cdot}1075\ CaO\end{matrix}\right\}$: $0{\cdot}278\ Al_2O_3$: $\left\{\begin{matrix}3{\cdot}25\ SiO_2 \\ 0{\cdot}454\ B_2O_3\end{matrix}\right.$

THE VALUE OF AGEING OF TERRA COTTA BODY.—R. L. Clare and R. N. Long (*J. Am. Cer. Soc.*, **4**, 453, 1921). It is shown that the terra cotta body when aged for a period of 12 days improves in plasticity, workability and strength. If the body is aged and subsequently repugged, still greater improvement is noted. This process is recommended as developing to the fullest extent the latent qualities of the body. The theory of this action appears to be a softening of the clay grains which, with the retempering

process, results in a finer subdivision of the particles and a more intimate combination of the clay and grog.

NOTE ON SAGGAR CLAY PREPARATION.—F. K. Pence (*J. Am. Cer. Soc.*, **4**, 459, 1921). For the better mixture of ingredients, thus improving the quality of the saggar, a mixing machine should be installed immediately following the dry pan. The soaking pit may then be eliminated, and the clay and water fed directly to the pug mill. This process permits of large tonnage and is, of course, also applicable to other bodies.

THE EFFECT OF THE REPLACEMENT OF FREE SILICA BY ALUMINA AND ZIRCONIA IN ELECTRICAL PORCELAIN.—R. Twells and C. C. Lin (*J. Am. Cer. Soc.*, **4**, 195, 1921). In order to determine whether free silica may be detrimental to the mechanical and dielectric strength of electrical porcelain, a series of 16 batches was prepared, in which various proportions of the free silica were replaced, weight by weight, by alumina, zirconia, or combinations of both. Bars and disks, after burning at cone $8\frac{1}{2}$ to 9, or at cone 12, were tested for shrinkage, transverse strength, impact strength, heat resistance, absorption of moisture and dye penetration. The results show that resistance to sudden temperature changes can be greatly improved by substituting zirconia, that the danger of over-burning can be greatly decreased by substituting alumina, and that the mechanical strength can be increased by substituting either or both. But in the case of dielectric strength, no improvement was obtained by substituting for free silica.

SHAPING, MOULDING, DRYING, ETC.

TEAPOT SPOUTS.—F. Tunnicliff (*Pat. J.*, 1,687, 1921). No. 160,694, June 2, 1920. The underside of the pouring-aperture of the spout of a teapot, jug, etc., forms an acute angle with the forwardly-curved breast, the apex of the angle being higher than the tip of the spout, thereby quickly getting rid of the last drops of liquid and preventing them running down the outside of the spout.

HOLLOW BRICKS.—H. Dean (*Pat. J.*, 1,688, 1921). No. 161,016, Jan, 31, 1920.

MOULDING PLATES, SLABS, ETC.—L. Cucurny (*Pat. J.*, 1,691, 1921). No. 162.262, Sept. 18, 1920. Description of a special type of mould for making plates, slabs, etc., of ceramic ware, by introducing the material in the form of moist powder into the mould and applying high pressure.

MOULDING POTTERY.—R. B. Thorburn and W. Boulton, Ltd. (*Pat. J.*, 1,692, 1921). No. 162,437, Feb. 16, 1920. In casting handles and other articles, a case of metal or metallic alloy with the handle in relief is used in the formation of the usual plaster moulds. The metal case is surrounded with a ring of oilcloth and the plaster is poured in to form the mould.

DRYING CHINA-CLAY.—C. J. Grace (*Pat. J.*, 1,685, 1921). No. 159,525, Aug. 23, 1919. The apparatus comprises a filter and a heated tubular drying-chamber connected to or in close conjunction with the filter through which the material is forced by a reciprocating rammer, screw, pump, etc. The clay may be discharged in a warm, moist condition, drying being completed by the contained heat either in a vacuum chamber or at normal pressure.

MOULDING HOLLOW-WARE.—C. H. Muckenhirn (*Pat. J.*, 1,685, 1921). No. 159,713, Jan. 2, 1920. Hollow earthenware parts, such as sanitary ware, are shaped in sections from a slab of clay by a succession of independent impressions between mould members. The sections are treated successively from the centre of the slab outwards and the final impression, besides shaping the last section, extends over the whole.

KILNS, OVENS, MUFFLES; FIRING TECHNIQUE, ETC.

BRICK AND LIKE KILNS AND DRIERS.—A. E. H. Beyer (*Pat. J.*, 1,686, 1921). No. 160,328, Jan. 16, 1920. In a combined continuous kiln and multi-chamber drying plant, the connecting flues and dampers are so

arranged that direct communication for the passage of air can be effected between any chamber of the kiln and any chamber of the drier, so that it is possible to utilize the heat remaining in burnt or dried goods in any way desired.

BRICK KILN.—J. Lewis (*Pat. J.*, 1,695, 1921). No. 163,439, Feb. 13, 1920. A kiln for burning bricks, etc., has a body of tubular form enveloped in an iron casing, and is provided with a number of apertures in the side walls, each of which serves as required as stoking-hole, draught connection and loading or unloading opening. The kiln walls slant outwardly, so as to increase the capacity upwards. An arrangement of kiln sections to form a continuous kiln is shown.

ANNULAR KILN.—H. Sturm (*Pat. J.*, 1,696, 1921). No. 163,973, Nov. 3, 1920. An annular kiln, combined with an annular drying-kiln, both provided with travelling soles, may be of large diameter and above the firing-kiln, or of the same diameter as, and arranged immediately above the firing-kiln. The goods pass completely round the drying-kiln and are then transferred to the firing-kiln, which is heated by fire-places opposite the charging point. The drying-kiln is heated by hot air from the cooling goods in the firing kiln.

TUNNEL KILNS.—J. Williamson (*Pat. J.*, 1,697, 1921). No. 164,376, Sept. 3, 1919. The ware is heated by a double circulation of air heated by a flue in a central longitudinal tunnel in the kiln structure below the oven space, which communicates at the top and bottom with the oven space. The kiln comprises heating, firing, and cooling zones, with gas-fired combustion chambers below and at one end of the firing zone, or in a double wall space at either side of the oven space.

ANALYZING GASES.—Svenska Aktiebolaget Mono. (*Pat. J.*, 1,691, 1921). No. 162,249, Apr. 19, 1921. Apparatus for carrying out two series of analyses is so arranged that in both series at least one constituent of the gas is always included ; for instances, in one series the percentage of CO_2 is determined, and in the other, the total percentage of CO_2, CO, hydrocarbon and hydrogen. The two series of analyses may be recorded on a common diagram.

DRAUGHT-INDUCERS FOR FURNACES.—E. Prat (*Pat. J.*, 1,693, 1921). No. 163,010, May 4, 1921. For inducing draught in a chimney, two fans delivering through separate passages and a common nozzle are employed, the lower part of the fan casing being enclosed by a plate which is so shaped as to offer very little resistance to the flow of gases in the chimney.

BRICK KILNS.—H. J. Alletson (*Pat. J.*, 1,694, 1921). No. 163,251, Dec. 10, 1920. In a multiple-chambered kiln, dampered passages are provided between adjacent chambers, a dampered flue leads from each chamber to the main flue, and above each chamber is a by-pass flue, by which air can be passed from any chamber to the next but one in the series.

GAS-FIRED KILNS.—J. H. Marlow (*Pat. J.*, 1,685, 1921). No. 159,522, July 23, 1919. In a gas-fired tunnel (or other) kiln, heating-gases are delivered to the kiln chamber through perforated conduits supplied from separate combustion chambers, and through perforations in the walls or arches. A tunnel kiln, with two lines of rails for trucks, has 3 perforated conduits, two running along the sides of the kilns and the third along the middle. Beneath these conduits are combustion chambers, supplied with gas from a producer. Flues formed of tubular sections or of perforated plates spaced from the main walls of the tunnel, lead from the side conduits. These flues may be separated from each other by a partition at the top. The products of combustion are exhausted by a fan through a jacket flue at the inlet and filled for part of its length with horizontally arranged pipes.

ELECTRIC FURNACE FOR CALCINING MAGNESIA, ETC.—F. S. Newall (*Pat. J.*, 1,686, 1921). No. 160,231, Dec. 9, 1919. The furnace comprises a moving vertical retort containing a stationary resistance with which the charge comes into direct contact.

FIRING CERAMIC WARE.—Allgemeine Elektricitäts-Ges. (*Pat. J.*, 1,687, 1921). No. 160,814, Mar. 29, 1921. The heating of the high-temp. zone of a tunnel oven is interrupted at intervals to allow the goods therein to cool down sufficiently to permit the trucks to be moved forward without risk of damage. The gas connections to two adjacent tunnels may be so arranged that their high temp. zones are fired alternately. During the interruption in firing, the temp. of the preliminary zone of the oven is maintained or increased by auxiliary burners. Cooling devices may be fitted in the cooling-zone and the heat abstracted may be used for drying.

KILN DAMPERS.—C. F. Bailey (*Pat. J.*, 1,690, 1921). No. 161,901, Sept. 8, 1920. The damper, adapted to be readily assembled within the "hovel" of brick and similar kilns, is constructed of 4 sections of refractory material clamped together by metal bands, which are accommodated in grooves in the circular edges and are tightened by bolts. In a modification adapted for down-draught ovens, the central flame hole is omitted.

SETTING A RECORDING PYROMETER FOR COLD JUNCTION TEMPERATURE.—L. W. Hopkins and K. Marsh (*Chem. Met. Eng.*, **25**, 180, 1921). A discussion of the subject in the correspondence column of the journal. The formula for the correction of cold junction temperatures varying from the calibrated cold junction temp. of the Le Châtelier (Pt.—Pt-Rh) couple, given by Hopkins, is as follows: $E=(t_1—t_0)x$, where E = actual error in deg. F., t_1 = cold end temp., t_0 = calibrated cold end temp., $x=0{\cdot}7$ for range 32 to 500°F., 0·6 for range 500–1,000°F., 0·5 for range 1,000–2,000°F. and 0·4 for range 2,000–3,000°F. The accuracy of this is disputed by Marsh, who states that the above formula gives the amount, to only a small degree of accuracy, which should be added to the reading of a pyrometer calibrated for a platinum-platinum + 10% rhodium thermocouple when the zero setting of the instrument agrees with the calibrated cold junction temp. while the actual cold junction temp. is higher or lower. The pointer should be set to the actual cold junction temp. instead of being advanced or set back by an amount as determined by the Hopkin's formula.

THE USE OF OIL IN CLEANING COAL.—G. St. J. Perrott and S. P. Kinney (*Chem. Met. Eng.*, **25**, 182, 1921). Coal, pulverised by wet grinding, is agitated with about 30% of oil, causing the formation of an amalgam of clean coal and oil and separation of a refuse practically free from combustible matter.

SELECTION OF FUEL FOR INDUSTRIAL HEATING.—(*Chem. Met. Eng.*, **25**, 116, 1921). Excerpts from a pamphlet published by the W. S. Rockwell Co. The various factors bearing on the selection of fuels for industrial heating are discussed. A chart is included, which gives means of comparing fuels on the basis of their B.T.U. costs—by direct comparison of the price of one fuel with that of another.

LABORATORY FURNACE FOR DEFORMATION TEMPERATURE OF REFRACTORIES.—L. R. Office (*Chem. Met. Eng.*, **25**, 162, 1921). The author claims no originality of principle for the type of furnace described, but outlines its development during four years of experience in obtaining the softening and deformation temperatures of various refractories. The "open-flame" type described by C. E. Fulton (*Trans. Am. Cer. Soc.*, **16**, 386, 1914), was the basis of this development. The furnace consists of two parts, the furnace proper and the preheater. Details are given by means of a sketch and a photograph.

APPLICATION OF ELECTRIC HEAT TO VITREOUS ENAMELLING.—L. E. Barringer (*J. Am. Cer. Soc.*, **4**, 461, 1921). A two-compartment open-chamber furnace with separating door operated from the outside is described. The source of heat is an electric current passed through a nichrome resistor ribbon wound over refractory supports arranged along the sides of the furnace. The front or preheating compartment is operated at 300°C. and the back or finishing section at 900°C., with automatic control. Compared

with oil heating, the advantages are : rejections reduced from 25% to zero ; 50% increase in output for the same floor space ; 47·4% lower fuel cost ; improved quality and uniformity ; lower maintenance cost and greater ease of operation. There are two photographic illustrations.

THE PRESENT POSSIBILITIES OF EMPLOYING WOOD IN THE CERAMIC INDUSTRY.—P. de Groote (*Cer.*, **24,** 1, 1921). The question of humidity is first discussed, and figures are given to shew that one ton of coal (of 6,000 cal.) is equivalent to about 4 cu. m. of hard wood, or 6 cu.m. of soft wood after 1 year's seasoning, *i.e.*, with about 20% humidity. Wood firing as applied to steam boilers, furnaces and gas generators is discussed at some length. It is shown that, with the same quantity of excess air, and with the secondary air at the same temp., the temperature of combustion of wood gas is always higher than that of coal gas.

DISCUSSION ON THE RATIONAL UTILIZATION OF FUELS BY THE SOCIETY OF CIVIL ENGINEERS OF FRANCE.—P. Appell (*Cer.*, **24,** 8, 1921).

FUEL ECONOMIES IN CERAMIC FURNACES.—P. Frion (*Cer.*, **23,** 121, 1920). A paper read at the general meeting of the Ceramic Manufacturers' Syndicate of France on May 10th, 1920. The subject is dealt with under the following headings : (1) Present situation ; (2) The science of heating,—the thermal balance-sheet ; (3) Different sources of economies, including—(*a*) possible improvements in combustion properly speaking, (*b*) reduction of calorific losses, and (*c*) the utilization of substitute fuels ; (4) The art of firing ; (5) Conclusion.

ON FIRING CERAMIC PRODUCTS WITH PETROLEUM.—J. T. Cadilhat (*Cer.*, **23,** 145, 1920). An account of the results obtained at an earthenware factory in Mexico (during the period July to September, 1919) using crude petroleum (fuel oil).

NATURAL AND ARTIFICIAL DRAUGHT.—M. Lebrasseur (*Cer.*, **23,** 149, 1920). An account of modern methods of producing satisfactory draught conditions. To produce a natural draught corresponding to 25 mm. water pressure with a chimney 30 m. high, the gases would have to be evacuated at a temp. of 600°C., which would mean a great waste of calories. Of the artificial draught producers, the preference is given to the under-grate blower.

THE TUNNEL-OVEN IN AMERICA.—M. Bauer (*Ber. D. K. Ges.*, **2,** 43, 1921). The paper gives a general description of Zwermann and Dressler kilns, the information being taken mainly from the *Trans. Am. Cer. Soc.*, 1915 and 1916, and the *J. Am. Cer. Soc.*, 1918 and 1920.

TIME AND TEMPERATURE OF BURNING AS FACTORS INFLUENCING THE CONSTITUTION AND MICRO-STRUCTURE OF A PORCELAIN BODY.—R. Rieke (*Ber. D. K. Ges.*, **2,** 51, 1921). A short discussion of Klein's paper (*J. Am. Cer. Soc.*, 1920, p. 978), reference being made to J. W. Mellor's work (Trans. **16,** 71, 1917) and Heath and Mellor's paper (Trans. **7,** 80, 1907).

AN ELECTRIC VITREOUS ENAMELLING OVEN.—C. W. Mehling and J. W. Carpenter (*J. Am. Cer. Soc.*, **4,** 271, 1921). The electric furnace eliminates damaged ware, in marked contrast with the coal, oil or gas furnaces, and the whole of its heating space can be utilised. Its initial cost and the fuel costs are double those of the older types, but it admits 25% increase in weight per charge and 30% in charges per hour. Details of construction are given, and methods of temperature record and control are explained. With an initial cost of $8,000, the cost of the electrical power has been $200 per hour for a 10-hr. day, which would be reduced to $1·56 per hr. for a 24-hr. day. With a production of 900 lb. of ware per hour the enamel finish is more satisfactory than with the older types of furnaces. Preheating chambers and double-end operation are suggested as future improvements.

THE SOLUBILITY AND FUSIBILITY OF SOME FELSPAR FRITS.—H. H. Sortwell (*J. Am. Cer. Soc.*, **4**, 446, 1921). In ceramic literature there is a lack of definite information on the solubility of frits for whiteware glazes. Twenty frits were made covering the field 10–50% fused borax, 20–90% felspar, and 0 30% calcium oxide. (1) The solubilities of the entire field were found to be less than 1·5%, showing that the variations in composition had less effect on the resulting solubility than the degree of smelting, and that all the frits were sufficiently insoluble for use in glazes. The inclusion of CaO in the frit had a beneficial effect in decreasing the solubility. (2) The fusibilities were found to vary from 660° to 1,050°C. Substitution of CaO for felspar up to 10%, maintaining the borax constant, increased the deformation point, but further substitution in this direction had little effect. Substitution of either CaO or felspar for borax appeared to raise the deformation temperature about the same in either case. A large part of the field was sufficiently fusible for easy working in the frit kiln.

A READING LIST ON VITREOUS ENAMELLING ON IRON AND STEEL.—C. J. West (*J. Am. Cer. Soc.*, **4**, 47, 1921). The list, which is a very full one, includes books, articles in periodicals and patents, commencing with the year 1907.

SOME DATA ON THE COMPOSITION OF ARSENIC ENAMELS FOR COPPER.—B. T. Sweely (*J. Am. Cer. Soc.*, **4**, 350, 1921). The methods of application are by the usual wet slushing, and sieving powdered enamel on to clean copper sheets and fusing to a smooth coat. Where slushing is necessary, it is advisable to use an enamel free from lead and arsenic as a ground. In this work the dry method is used exclusively. In the formulae given, an increase of SiO_2 increases fracturing and shivering, increase of B_2O_3 above 0·2 equiv. in the presence of 0·1 equiv. of As_2O_3 causes enamels to come out matt. Increasing KNaO at the expense of PbO decreases the opacity, improves the fit and the gloss, but makes the enamel more soluble. The following limits in composition are recommended : 0·3 to 0·7 KNaO, 1·3 to 1·8 SiO_2, 0·7 to 3 PbO, 0·0 to 0·2 B_2O_3, 0·05 to 0·15 As_2O_3.

NICKEL OXIDE IN GLAZES.—J. D. Whitmer (*J. Am. Cer. Soc.*, **4**, 357, 1921). The literature on the subject, published in the *Trans. Amer. Cer. Soc.*, is briefly reviewed. Red colours are produced when ZnO and BaO are used in certain proportions. Blues and purples of varied shades and lines are developed with varied combinations of ZnO, CaO and BaO. Grays are possible in the presence of CaO and MgO.

ENAMELS, GLAZES, ETC.—A. A. Kelly and B. D. Jones (*Pat. J.*, 1,687, 1921). No. 160,495, Nov. 20, 1919. In the manufacture of glass, vitreous enamels and glazes, sodium pentaborate is substituted for borax or boric acid, and the necessary adjustment of the alkali content is made in any suitable manner.

THE EFFECT OF GLAZE COMPOSITION ON THE CRAZING OF TERRA-COTTA.—E. C. Hill (*J. Am. Cer. Soc.*, **4**, 25, 1921). The effects of equal molecular additions of the various components of glazes were studied, and it was found that ZnO and felspar overcome crazing, ZnO being the more effective. MgO, BaO and CaO tend to produce crazing, MgO having the greatest tendency and the effect of BaO being somewhat greater than that of CaO. SnO_2 has no effect on crazing. The addition of small quantities of clay is more effective than much larger additions, or substitutions of other components. Increase of flint (per molecular equivalent) is less effective than increase of clay, ZnO or felspar, although, generally, considerably more flint than clay or ZnO can be added without appreciably changing the maturing point of the glaze. In many cases, increase of flint will not overcome crazing in a glaze.

COLOURS, DECORATIVE PROCESSES, ETC.

THE MUTUAL RELATIONS BETWEEN ART AND TECHNOLOGY.—L. V. Solon (*J. Am. Cer. Soc.*, **4**, 263, 1921). An analysis of the purpose

of decoration and of the characteristics of bodies, colours and glazes, which determine their acceptability for the purposes of the decorative artist. The author urges the establishment of an annual exhibition where American ceramic artists may exhibit their products along side those of the sculptors, mural painters and other artists.

NOTE ON COBALT STAIN IN WHITEWARE BODIES.—A. S. Watts (*J. Am. Cer. Soc.*, **4**, 451, 1921). Cobalt oxide or directly added cobalt sulphate frequently causes a blue-gray cast when the body is hard fired. *To prepare* the stain correctly, add 15 ozs. pure cobalt sulphate ($CoSO_4$ $7H_20$) to 750 ozs. of pure water and stir until dissolved. Then add 7·5 ozs. of Na_2CO_3 and stir thoroughly. Before adding the stain, ball clay must be thoroughly blunged with the body. If used in a casting slip, the stain should be added as part of the casting solution. The *proportions* are as follows :— For a body containing 10% ball clay add 75 ozs. stain solution to each 1,500 lbs. body, *i.e.*, ½ ozs. stain for each 10 lb body. For bodies with higher ball clay content, increase the stain solution in the same ratio up to 15% ball clay. For *glazes*, add 10 ozs. stain to each 100 lb. dry glaze batch when the latter is thoroughly wet in the mill. For glazes high in lead, the amount of stain required is increased.

PLANT AND MACHINERY, ETC.

GRINDING MILL.—W. F. Malkin (*Pat. J.*, 1,692, 1921). No. 162,481, Mar. 8, 1920. In grinding mills of the open pan type, a pillar fixed in the centre of the pan supports a wheel, the arms of which carry blocks of wood or other suitable material and the wheel is driven from its circumference by bevel, spun, belt, or other gearing. Bevel teeth around the lower edge of the wheel rim gear with a bevel wheel on a driving-shaft. The bottom of the pan is paved with stones, and the sides are constructed of, or lined with, stone, porcelain, wood, metal, cement, etc. An arrangement for extracting the rough particles from the finest is described.

PULVERISERS.—A. M. Read (*Pat. J.*, 1,696, 1921). No. 163,856, Mar. 19, 1920. Relates to pulverisers of the ball-and-barrel class.

IMPROVEMENTS IN TUBE MILLS.—R. H. Vail (*Rock Products*, **24**, No. 9, 39, 1921). According to the writer, the closed-circuit system of grinding and air separation, have increased the grinding capacity of tube mills from 15 to 25 per cent. The system has been more extensively applied in the metal-mining industry. It consists in overfeeding the mill, and letting it discharge before all the material has been reduced to the required fineness. The product is then classified and the material which is too coarse, is returned to the mill. The difficulty of discharging its finished product was long a drawback of the tube mill. Closed-circuit grinding may be characterized as a "device" to get the finished product out of the mill more quickly. The system has been applied to a more limited extent to the dry-grinding cement plants, and has resulted in the above-mentioned increase in their output. The direct air-separation of the finished particles has lately been applied to tube mills. This method has the following advantages over closed-circuit grinding : It avoids returning to the mill the large circulating load and it removes more quickly the finished particles. The tube-mill, equipped with direct air-separation, should add to the increased efficiency obtained under the closed-circuit system of dry grinding with the tube-mill and Emerick separator.

MOULDING BRICKS, BLOCKS, ETC.—F. T. Gray and Whitaker, Ltd. (*Pat. J.*, 1,686, 1921). No. 160,306, Jan. 2, 1920. Description of a machine.

GYRATORY CRUSHERS.—J. E. Kennedy (*Pat. J.*, 1,686, 1921). Nos. 160,463/5, Feb. 20, 1920.

JOLLIES.—J. Mills (*Pat. J.*, 1,690, 1921). No. 161,763, Feb. 7, 1920. Describes an adjustable tool carrier, comprising a sliding block within a guide-plate.

GRINDING MILL.—M. J. Davidson (*Pat. J.*, 1,690, 1921). No. 161,977, Apr. 13, 1921. A mill for reducing material to an impalpable powder in three stages consists of a rotary drum divided into 3 compartments and containing loose grinding bodies of decreasing size and weight.

MOULDING SILICA BRICKS.—C. L. Norton (*Pat. J.*, 1,692, 1921). No. 162,423, Feb. 9, 1920. A machine is described for making silica bricks composed of granulated ganister rock or similar materials by dropping a quantity of the granules into a mould, the conditions being such that the granules in dropping separate slightly so as to constitute a closely assembled but discrete aggregate on arrival within the moulds.

III.—FINISHED PRODUCTS: TESTING, ETC.

TRANSMISSION-LINE INSULATION IN AMERICA.—F. W. Peck (*Electr. World*, **76,** 1,061, 1920). The article presents the author's findings after a thorough study to ascertain if there are sound theoretical, practical and economic reasons for the line-insulation standards which have grown up in America. Discussing the effect of lightning on insulators, it is pointed out that insulators of different designs may have equal normal frequency spark-over voltages but widely different impulse or lightning spark-over voltages. This is because a definite but very small time is required for a spark to form, which depends upon the design and upon the rapidity at which the voltage is applied. Higher voltages are required in the case of lightning where they are applied very rapidly and the time is, therefore, limited. Such rapidly applied voltages are said to have a steep wave-front. Spark-over does not occur when the normal frequency spark-over voltage is reached by the rapidly increasing impulse voltage, but some time later when this voltage has reached a higher value. The ratio between the impulse spark-over voltage and the normal frequency spark-over voltage has been termed the impulse ratio. This ratio is very high for steep wave fronts and approaches unity for "low-frequency" surges. For a given impulse, the impulse ratio is lower for smooth insulators than for insulators with properly designed petticoats or corrugations. This is illustrated in the following table :—

IMPULSE SPARK-OVER OF INSULATORS.

Type	Spark-over Kv., 60-cycle		Impulse Spark-over Kv. (Single half-cycle, 200 Kilocycles Sine Wave)		Impulse Ratio
	Dry	Wet	Dry	Wet	
Petticoat..	100	67	142	140	1·42
Smooth ..	100	50	105	105	1·05

Lightning would be less likely to cause spark-over of insulators of the first type ; rain does not greatly decrease the lightning spark-over. The effect of steepness of wave front may be seen from the following :—

IMPULSE SPARK-OVER OF SUSPENSION INSULATORS.

	60-cycle Spark-over Kv.		100 Kilo-cycle Impulse Spark-over		500 Kilo-cycle Impulse Spark-over	
	Dry	Wet	Dry	Wet	Dry	Wet
A. Two-piece suspension with petticoats ..	112	72	118	114	165	162
B. Two-piece suspension with petticoats ..	116	70	128	125	172	168

The spark-over voltage of an insulator or bushing decreases with the air density, or pressure and temperature. Generally, it decreases approximately as the air density. The correction factor is calculated as follows :— $\delta = (3{\cdot}92b) \div (273 + t)$, where b = barometric pressure in centimetres, t = temperarture in deg. C.

The apparent deterioration of porcelain is generally due to one of the following causes : (1) Gradual mechanical cracking due to expansion of cement or tight-fitting metal parts, or to internal firing strains or brittle porcelain. (2) Gradual absorption of moisture due to porosity. The greater part of the trouble was found to be due to the first cause. The type of insulator in which the porcelain units are strung together by loose-fitting metal parts shows no deterioration after ten years of service. The absorption of moisture seems to be due to a considerable extent to breathing. The presence of a damp sponge of cement is thus also undesirable, since it keeps moist the air breathed by the porcelain. In a discussion of electrical tests, it is mentioned that no test is at present known that will anticipate mechanical failure or detect porous material when dry. The 60-cycle test, at operating frequency, is the best for general use and is most practical. It will readily puncture porous insulators that have absorbed moisture. Damped high-frequency tests are often made, usually at about 100 kilocycles. This is obtained from an oscillating circuit giving 120 very highly damped wave trains per second. It acts as a series of impulses. It will not detect old porous insulators that have absorbed moisture. The discharge has a tendency to spread over the insulator surface, and it may thus detect flaws in the petticoats more readily than some other tests. The impulse test is of use as a design test in determining the impulse ratio, etc. Undamped high-frequency tests will cause failure in insulators at very low voltage because of heat, but it is a condition that does not occur on transmission lines. The direct-current spark-over voltage is approximately $\sqrt{2} \times$ the 60-cycle spark-over voltage. The puncture voltage is relatively much higher. The 60-cycle test has the desirable characteristics of all the other tests, except that possibly it does not so readily detect flaws in petticoats. This feature, though not always important, can be added by making the arc of the insulator part of an oscillatory circuit by limiting the current in the arc by resistance. By this means, the oscillatory wave is superposed upon the 60-cycle wave.

FEATURES OF EUROPEAN INSULATOR TESTING PRACTICE.—B. Schapira (*Electr. Rev.* **77**, 721, 1920). The article gives an illustrated description of the detail of European testing practice as carried on in the Schomburg Works at Margarethenhütte, Germany. For working pressures up to about 50,000 volts, pin-type insulators, mostly of the delta-bell kind, are used almost exclusively. The two parts of the insultor are made and baked separately and are then joined together with pure Portland cement. In consequence, thinner, and more perfectly made sections of porcelain can be used, and in addition, the two parts may be tested separately, the combined testing voltage being much in excess of what would be allowed for an insulator of one part only. The upper section of a delta-bell insulator would be tested with 35,000 volts, and the pin section with a pressure of 25,000 volts, making a total puncture test of 60,000 volts. Moreover, the cement between the two sections aids in distributing the electrical stresses and so adds further to the safety of this construction. Disruptive tests are made under oil, since the high pressures necessary lead to spilling over in air. An average of 110,000 volts is required to puncture a well-made unit.

AIR TESTS ON DELTA-BELL INSULATORS.

Working Pressure.	Test Pressure.
10,000 volts	60,000 volts.
30,000 ,, ...	100,000 ,,
50,000 ,, ...	135,000 ,,
70,000 ,, ...	200,000 ,,

OIL TEST DISRUPTIVE VOLTAGES FOR DELTA-BELL INSULATORS.

Working Pressure.	Disruptive Strength.
10,000 volts.	110,000 volts.
30,000 ,, ...	140,000 ,,
50,000 ,, ...	170,000 ,,
70,000 ,, ...	200,000 ,,

For insulators of 70,000-volt capacity three parts are cemented together, such construction allowing the above extremely high testing voltage. Rain tests are conducted with special laboratory equipment intended to produce conditions similar to those prevailing in actual outdoor service. Fog is imitated and rain of varying intensity and from different angles is projected into the insulator carrying a live wire. Several photographic illustrations of insulators undergoing this test are given. With regard to mechanical strength, it is stated that a thorough baking at a temperature of 1,650°C. produces porcelain of a quality hard and strong enough to resist any strains that may be applied to delta-bell insulators. The figures in the following table represent conditions where insulators are fitted to their pins with hemp packing.

MECHANICAL STRENGTH OF DELTA-BELL INSULATORS.

Working Pressure.	Least Breaking Load.	Sagging Load.
10,000 volts ..	3,500 lbs. ..	610 lbs.
30,000 ,, ..	5,000 ,, ..	1,100 ,,
50,000 ,, ..	6,800 ,, ..	1,870 ,,
70,000 ,, ..	8,900 ,, ..	2,640 ,,

Cement and similar binding materials give greater strength, but are not recommended for the larger insulators, because of the resultant restriction to the free expansion and contraction under changing temperature conditions of the pin, binding material and insulator. Insulators of the delta-bell type increase in size and weight more rapidly than in capacity, the 70,000-volt size being about five times as heavy as the 50,000-volt size.

THE POROSITY OF PORCELAIN, WITH SPECIAL REFERENCE TO HIGH-PRESSURE INSULATORS.—C. C. Farr (*New Zealand J. Sc. and Tech*, **2**, 302, 1919). Experiments were carried out at Canterbury College with a view to ascertaining whether or not the porcelain, of which the insulators on the Lake Coleridge transmission-line were made, was of a porous nature, since some of the failures of these insulators seemed ascribable to this cause only. For the purpose of the tests, a cylindrical cavity 3 in. in diam. and $6\frac{1}{2}$ in. deep was bored into a solid block of mild steel of rectangular cross-section measuring $5 \times 5 \times 9$ inches. A well-fitting cover of the same steel, 1 in. thick, was bolted over the cavity, in which, by the aid of a gas-compressing pump, a pressure of 2,000 lb. per sq. in. could be maintained for many hours. Specimens cut from different parts of the insulators were immersed in fuchsin and subjected to a pressure of about 2,000 lb. per sq. in. for 50 hours. Tests were carried out on 10 pieces each of glazed and unglazed porcelain from 3 different shipments by two makers. The results are tabulated. The specimens were afterwards broken in chosen lines. A photographic illustration shows the penetration of the dye under pressure. The following conclusions are drawn from the experiments:—(1) That density and porosity have little or no connection with one another. (2) That porcelain can be made which shows no penetration under the pressures which were maintained, and for the times for which they were maintained, in these experiments. (3) That, when porcelain is not so made, a porous layer or core with abrupt edges very often exists in the mass of the substance.

NOTES ON HIGH-TENSION INSULATORS.—L. Birks and G. F. Ferguson (*New Zealand J. Sc. and Tech.* **3**, 177, 1920). Investigations were carried out by the authors on behalf of the Public Works Department to locate the cause and devise means of reducing breakdowns on the 66,000-

volt transmission-lines from Lake Coleridge to Christchurch, New Zealand. During 4 years of service, a little over 5 per cent. of the insulators broke down. The bulk of the replaced insulators was taken from a section of the line which is most subject to mists and fogs, the latter being probably laden slightly with salt swept from a large salt-water lagoon about 10 miles distant from the lines. In certain circumstances, breakdowns were found to be directly associated with atmospheric conditions, and experiments were made to determine the effect of misty conditions. An insulator was placed in a wooden box into which water-vapour was admitted from a small boiler. The humidity was measured by means of wet and dry-bulb thermometers inside the box. Four curves are given, showing the result of tests made (1) by connecting the megger across the top shell, neck groove to joint, and (2) with the megger leads connected from neck groove to the first cement joint, the humidity being increased slowly; these tests were repeated with the insulator surfaces dusted with road dust. The curves show clearly the effect of a humid atmosphere in reducing surface resistance. An interesting test, approximating more nearly to actual conditions, was carried out by putting the insulator under a pressure of 40,000 volts into the humidity-box and then raising the humidity to a high degree. The curves show that the surface resistance fell rapidly to 300 megohms and remained stable at that value. Voltage was then removed, and the resistance dropped to about 50 megohms, at which value it showed a tendency to become steady. Pressure was then again applied, and gradually raised to 40,000 volts, the surface resistance again increasing to 300 megohms. In practice, it was found that if pressure were taken off a line during misty conditions and put on again gradually within a few minutes, it was not so liable to break down as if a longer period were allowed. Apparently there is a condensation of moisture on the surface which requires an appreciable time to take place and is prevented as long as pressure is maintained, but proceeds gradually as soon as pressure is removed.

With regard to the effects of temperature changes, no sign of cracking was observed during the first two years of operation, but after the 4th year, about 36 insulators were removed, cracked badly in the top shell. This cracking was almost certainly due to unequal expansion and contraction of the porcelain and cement. The following test was applied to four insulators, which had been stored in the open for about 2 years. The insulators were plunged into boiling water and allowed to remain for a few minutes, after which they were immersed in cold water at about 60°F., the cycle being repeated 3 times. The top shell of one of the insulators cracked, the others remained unaffected, whilst two others of a different make, the top and second shells being integral, cracked badly on the first transfer to cold water. Some investigation was carried out to determine the effect of the absorption of moisture by the porcelain on the serviceability of the insulators. Ordinary red ink applied to the broken surfaces of insulators showed that the porcelain was decidedly porous in places, while in other places it appeared to be more vitrified. With regard to the design of high-tension insulators, the whole question is raised as to whether the large quantity of porcelain usually employed would be essential if a perfectly vitrified material were available. If the manufacturers could guarantee such a material, both the number and the size of the shells required might be reduced. In conclusion, it is stated that (1) the length of service of an insulator, either of the pin or suspension type, is partly a question of design, but depends mainly on the care with which the pieces are manufactured and fired, the firing of the ware being apparently the most important operation; (2) temperature stresses cause many failures, and this problem appears to be the most difficult to overcome, but improvement in the design of the insulators will no doubt reduce these troubles; (3) the installation of protective apparatus to reduce the effect of transient high voltages would minimize the risk of punctured porcelain.

THE CORROSION OF COKE OVEN WALLS.—A. E. Findley (*J. Soc. Chem. Ind.*, **40**, 7 (T), 1921). The work described was carried out with a

view to throwing some light on the effect of certain ingredients in the coking slack on the corrosion of the oven walls. The ingredients suspected of being most harmful were salt, iron and moisture. The conclusions drawn are as follows: (1) As the amount of salt increases the durability of the oven walls decreases. (2) If the amounts of both salt and iron present are high, durability seems to be still further diminished. (3) Iron and moisture may be present in relatively large amounts without appreciably affecting the durability if the salt-content is very low. (4) The higher temp. in vertical flues of a regenerator oven system tends to shorten the life of oven walls.

THE MECHANICAL PROPERTIES OF PORCELAIN AND EXACT METHODS OF TESTING.—E. Rosenthal and F. Singer (*Elektrotech. Zeits.*, **41**, 705, 1920).

THE TRANSVERSE STRENGTH OF FIRE-CLAY TILES AT FURNACE TEMPERATURES.—R. F. Geller (*J. Am. Cer. Soc.*, **4**, 608, 1920). Commercial fire-clay tiles were tested at furnace temperatures for transverse strength. This was supplemented by tests on tiles of known composition made in the laboratory. The moduli of rupture obtained varied from 245·5 pounds per sq. in. at 1,275°C. to 28·9 pounds at 1,350°C., but the data collected do not warrant definite conclusions.

STANDARDS FOR CLAY PRODUCTS, CEMENT, LIME AND GYPSUM.—(*Amer. Soc. for Testing Mat., Book of Standards*, 1921, p. 530). This publication, which is issued triennially, contains the following under Section C:—(1) *Standard Specifications for*: Portland Cement; natural cement; drain tiles; paving bricks; building bricks; clay sewer pipes; cement-concrete sewer pipes; gypsum plaster; fire tests of materials and construction. (2) *Standard Methods of*: test for refractory materials under load at high temperatures; test for porosity and permanent volume changes in refractory materials; test for softening point of fire-clay bricks; ultimate chemical analysis of refractory materials including chrome ores and chrome bricks; test for unit weight of aggregate for concrete; making and storing specimens of concrete in the field. (3) *Standard Definitions*: Of terms relating to sewer pipes; for clay refractories. (4) *Recommended Practice for*: Laying sewer pipes.

TESTING COKE-OVEN REFRACTORIES.—F. A. Harvey and E. N. McGee (*J. Am. Cer. Soc.*, **4**, 474, 1921). General requirements are stated for the concrete mat, bench walls, checker work, regenerator korbels, main flues, division walls, oven chambers and jamb blocks. The following tests are described: inspection, reheating tests on three qualities, bending test. Under "inspection" are included: measurement for size, degree of warp, ring under the hammer test, and any departure from standard samples on colours, bond, vitrification or workmanship. A number of instructions, based on an extensive experience, are given for the guidance of mason foremen and inspectors. Requirements and specifications are discussed. The latter part of the paper deals with *apparent density*, and *permanent expansion*. It is shown that the relation between them is a linear one and a chart is given. The average of 39 determinations gives an apparent density, for Western bricks, 0·016 higher than for Pennsylvania bricks, due to the fact that the Western ganister is slower to transform than the Eastern.

REFRACTORIES FOR OIL-FIRED FURNACES AND BOILERS.—W. H. Grant (*J. Am. Cer. Soc.*, **4**, 390, 1921). The failure of fire-bricks in oil-fired furnaces results from (1) spalling and falling of side wall bricks, (2) disintegration of bricks in the direct path of the flame, (3) glazing of the surface with a green glaze which penetrates and weakens the bricks, and (4) erosion by the flames. A plea is made for more research in the field.

NATIONAL (AMERICAN) REVIEW OF THE SAGGAR SITUATION.—G. Simcoe (*J. Am. Cer. Soc.*, **4**, 393, 1921). A questionnaire sent to a number of clay manufacturers elicited the following information: (1) better saggar-

cost system needed ; (2) carborundum and sodium silicate are frequent constituents of the saggar body ; (3) jaw-crusher is better than pan grog ; (4) a saggar containing 30% carborundum and lasting 20 or more fires is economical.

NOTE ON THE ACID RESISTANCE OF ENAMELLED COOKING UTENSILS.—B. T. Sweely (*J. Amer. Cer. Soc.*, **4**, 407, 1921). Experiments on trial pieces with poured samples, and with enamelled ware from various manufacturers showed that the surface of the layer of enamel which is uppermost during firing and cooling is readily attacked by acid, thus indicating, apparently, that the more soluble materials tend to rise to the top of the melt. It is therefore recommended that enamelled kitchen ware be fired in an inverted position. In the discussion, B. A. Rice describes a series of such experiments, using small shallow cups. Quantitative tests failed to show any difference in acid resistance, and it is suggested that the author's results were due to the nature of the gases in contact with the enamelled surface or to volatilization. In his reply, the author accepts this explanation of his results.

TESTS OF FIRE-BRICKS MADE FROM GANISTER, FLINT-CLAY AND PLASTIC CLAY MIXTURES, WITH SPECIAL REFERENCE TO SPALLING.—R. M. Howe and M. Sheppard (*J. Am. Cer. Soc.*, **4**, 206, 1921). Five experimental batches of fire-bricks were made by mixing various proportions of ganister, flint clay and plastic clay in such a way as to vary the silica content from 53 to 77% and the alumina content from 43 to 20%. The fusion points were found only slightly lower than those of corresponding pure silica-alumina mixtures. Load tests at high temperatures showed that the behaviour under compression does not depend on chemical composition so much as on factors such as the temp. of burning. The resistance to spalling, as tested by alternate heating and dipping in cold water, was found to decrease as the burning temp. was increased from 1,300° to 1,400°C. The higher silica bricks were relatively more resistant at the lower temp., but not so at 1,400°. The substitution of ganister for flint clay, therefore, increases the resistance to spalling at moderate operating temperatures but is of no advantage at 1,400° or above.

THE USE OF PLASTIC CLAY GROG IN PREVENTING SPALLING.—R. M. Howe and S. M. Phelps (*J. Am. Cer. Soc.*, **4**, 119, 1921). Coarse grinding, soft burning, and a uniform open structure of fire bricks favour high resistance to spalling. Where two or more clays are available, the use of a large proportion of open-burning clay is desirable. To test the effect of calcined clay grog on the properties of fire-bricks, a medium dense-burning clay was calcined at cone 8, then ground and mixed with plastic clay in various proportions up to 40%. An air spalling test of the burned bricks showed that the grog increased the resistance to spalling by about 5% for each per cent. of grog added. The results for other physical properties agreed with those found by previous observers ; the bricks with grog were more porous and weaker mechanically, but showed less drying and burning shrinkage.

A STUDY OF SPALLING.—R. M. Howe and R. F. Ferguson (*J. Am. Cer. Soc.*, **4**, 32, 1921). When fireclay bricks are subjected to repeated temperature changes, or to unequally distributed or excessive stresses (in arches), pieces become loosened and the bricks are said to spall. This statement is given as the generally accepted conception of spalling. The test originally adopted as a temporary standard was as follows : The dry test specimen was weighed in grams and placed in the door of a furnace operating at 1,300–1,350°C., care being taken to prevent the direct heating of more than the $4{\cdot}5 \times 2{\cdot}5$-inch end. After one hour, the specimen was stood on end in a tank of flowing cold water, so that the hotter portion of the brick (5 inches) was immersed. When pieces became loosened and fall off, the sample was laid on a $4{\cdot}5 \times 9{\cdot}0$-inch asbestos board, subdivided into 100 equal squares, and the approximate percentage of loss estimated. The results of several of these tests are plotted on curves and tabulated. The conclusion was

drawn that the usual spalling test gives accurate information when the specimens are made from the same fireclays, but when fireclays from different districts are compared, the results are not in accordance with their behaviour in service. It is known that when firebricks spall in service the pieces are usually dense or vitrified. Consequently, the possibility of a relation between vitrification and spalling was suggested. In order to develop this relation, specimens of a firebrick were prepared by heating for five hours at 1,200°, 1,300°, 1,400° and 1,450°C., the vitrification of the various stages thus depending upon the highest temperature to which the different samples had been heated. The reheated samples were then subjected to the usual spalling test, with water as the cooling medium. When each specimen lost over 33% the number of immersions necessary to produce this failure was recorded as its spalling value. These data were collected and plotted, and they show very clearly that resistance to temperature change is a function of vitrification. Summarizing, it is said that a relation is shown between porosity, vitrification and spalling, for as vitrification increases, resistance to spalling decreases, and since vitrification is associated with porosity decrease it is believed that the following statement is justified: Fire-clays, which undergo a slight change in porosity when heated over a wide range of temperature, have a very slight tendency to vitrify, and are therefore particularly adapted to the manufacture of non-spalling fire-bricks. In view of the results obtained, it became evident that a broader interpretation would have to be given to spalling, and the following statement is put forward to meet this requirement: When portions of fire-bricks become loosened in service under the influence of fluctuations in temperature, they are said to spall; density due to vitrification, improper brick structure, and unequally distributed stresses facilitate this action. Within the past year, certain hand-made special shapes, made of equal proportions of a dense-burning clay (Y) and an open-burning clay (X), were found to spall badly in service, though when water spalled they lost less than 3% after 20 immersions. The batch was therefore changed so as to include only 20% of Y, after which spalling ceased, showing that spalling is not always due to improper fire-brick structure, but is largely controlled by the thermal properties of the raw clays. On the whole, the results appear to warrant the following conclusions: (1) Air-cooling and water-cooling spalling tests give similar results; (2) These results lead to accurate conclusions where the same fireclays are involved, but misrepresent the facts when different clays are concerned; (3) These discrepancies may be overcome by reheating the test specimen before subjecting it to the spalling test; (4) The necessity for reheating arises from the great differences in the vitrification behaviour of different fireclays; (5) Vitrification is closely associated with spalling.

NOTE ON SILICA BRICKS.—D. W. Ross (*J. Am. Cer. Soc.*, **4**, 65, 1921). The writer had the opportunity of examining bricks after extended use in tank furnaces used in the manufacture of bottle glass. Rough data were kept concerning the silica brick crowns, and the general conclusions arrived at are summarised as follows: (1) Great care is necessary in heating up a new crown, owing both to the large expansion of the whole crown and to unequal expansion from place to place, some spots expanding considerably more than others. (2) After 18 months (or more) service, a crown can usually be cooled without disruption, provided the temp. does not drop too rapidly after the fires are turned off. (3) A crown so cooled, gives less trouble on reheating than when first heated up, since it only expands one half as much as before. (4) After a crown has been in use 18 months, a large percentage of the bricks are broken in two, or at least contain a zone of weakness approximately midway between the inside and outside of the crown. Microscopic examination indicated that the interior of the crown was practically all tridymite but contained slight amounts of calcium monosilicate crystals and glass. No quarts whatever was present. The smaller expansion and the ability to withstand more rapid heating shown by used crowns is due to this preponderance of tridymite. The fact that one end of the bricks is largely

tridymite while the other end is mostly quartz and cristobalite may have an important bearing on the cracking of the bricks at or near the centre.

THE INSULATOR SITUATION.—V. D. Peaslee (*Trans. Am. Inst. El. Eng.*, **36**, 527, 1917). The paper gives a résumé of the insulator situation as it then existed, and shows the gradual increase in requirements that have been held essential to a successful insulator. A statement of the apparent causes of the very rapid deterioration of insulators, even when stored and subject to no electric stress is given, and the conditions necessary to the production of an insulator that will reduce this deterioration cost are discussed. Microphotographs showing the structure of the porcelain from several insulators are given and flaws and defects common to porcelain insulators are shown. The use of fused quartz is indicated as a means for improving the situation.

INSULATOR FAILURES UNDER TRANSIENT VOLTAGES.—W. D. Peaslee (*Trans. Am. Inst. El. Eng.*, **35**, (II.), 1195, 1916). The operation of a high-voltage transmission line involves changes in energy distribution which are very conducive to high-frequency disturbances and transients of very steep front. These are often superposed on the normal frequency voltage of the line in such a way as to impose great stresses on the insulators. The results of investigations on the failure of insulators under impact and combined impact and normal frequency voltages are given in this paper, and microphotographs of the resulting failures are included. The duration of the stress in determining the magnitude of the voltage necessary to puncture an insulator is discussed. Due to the short duration of transients, insulators are often punctured repeatedly by them, the porcelain in the puncture solidifying again on account of the small energy involved. These sealed punctures, however, weaken the insulator, lowering its dielectric strength materially. The importance of the elimination of air holes and defects in the porcelain is shown. Some essential features of a successful line insulator are stated.

TESTING THE WHITE COLOUR OF PORCELAIN, KAOLIN AND CLAY.—W. Funk (*Ber. D. K. Ges.* **2**, 39, 1921). Pure whiteness of colour is an important consideration in the manufacture of good-quality table porcelain. The means whereby this desired object may be attained are familiar to every experienced manufacturer. Since the pre-war period, conditions have completely changed, so that quality, and not cheapness of the ware is now the best guarantee of successful competition in the world market. From this point of view, therefore, it would appear to be essential for every make of table porcelain to test his ware very carefully ; he cannot afford to be content with a mere subjective examination. A valuable aid for testing purposes is the Ostwald system of colour classification (*Trans.* **20**, *Abs.* 89, 1921). Much that in everyday life is called "white" has, strictly speaking, no claim to be designated as such. Even freshly-fallen snow is no exception to this. Physics teaches us that an absolutely white surface is one which reflects *all* light uniformly in all directions. The whitest paper known reflects only 85% of the light which strikes its surface ; it is therefore not white, but gray, with 15% of "black" in it. A surface, which most nearly approaches an ideal white, is obtained, according to Ostwald, by covering paper repeatedly with precipitated barium sulphate and rendering the surface perfectly smooth by lightly rubbing over with a piece of similarly treated paper to remove the traces of the brush. A surface thus produced is known as "normal white." For testing the white-black content of porcelain colours, Ostwald has constructed a "Gray-scale" or "ladder," which is obtainable from the Unesma Verlag, Leipzig. It consists of a frame measuring 320×57 mm. and containing the following white-black grades : 100, 95, 90, 85, 80.....20, 15, 10, 08, 06, 04, 02, these figures representing the percentage of white in each grade. With the help of this "scale," the white content of a porcelain colour can very readily and conveniently be determined. If the porcelain has a yellowish shade, the white content may still be determined in the same way by carrying out the test in coloured light. Light

filters for this purpose are also supplied by the above firm. The same tests can, of course, be applied to kaolins and clays in the raw and fired state. Perfectly "bright" colours, that is, those with no black or gray content, are difficult to prepare in ceramics, but if the gray content of the colour corresponds more or less with that of the porcelain body, a satisfactory and harmonious effect is assured.

IV.—MANAGEMENT, ORGANISATION, COSTING, ETC.: COMMERCIAL.

THE GERMAN CERAMIC INDUSTRY.—(*Morning Post*, Sept. 22, 1921). A special correspondent gives a general survey of the conditions, primarily from the point of view of the ability of the industry to bear its fair share of the reparation payments. It is pointed out that the industry is very highly developed, and that the necessary raw materials, with few exceptions, can be obtained in Germany itself. Before the war, the various branches of the glass industry employed over 100,000 workers. The chief centres of pottery production are the Saar valley, Rhineland (around Cologne), and Saxony. The first specimens of German porcelain were naturally very crude and quite inferior to the Japanese product, but the intimate co-operation between the chemical and electro-technical industries and the porcelain factories induced the latter to concentrate on research, with the result that even to-day German technical porcelain holds a leading position in the world market. The whole ceramic industry is now, however, handicapped by the growth of outside competition, particularly that of Japan, by the scarcity of fuel, and by the difficulties arising out of such political changes as the creation of Poland and Czecho-Slovakia into independent States. Many German porcelain factories had their branches in Bohemia before the war, so as to secure their kaolin supply; they sold technical ware in Bohemia in exchange. The freedom of this exchange is now seriously impeded by the political barrier raised by the Peace Treaty, an obstacle similar in its deterrent action to the Rhine Customs barrier. Strenuous efforts are therefore being made by the German manufacturers to render themselves independent of Bohemian kaolin and brown coal, and it is generally recognised that the future of the industry depends on wide-spread and systematic research. To keep pace with the advance of technique in the porcelain-using industries, it is necessary that such research should be well paid, each works having its own regular investigators. But the porcelain industry has never been rich, the factories are mostly small family possessions, without large capital for maintaining the heavy expense of research work. Further, the heavy burden of taxation, the loss of markets through the war, and the rise of new competitors in England, America, and especially Japan, make it impossible for the small manufacturers to keep up the struggle. The result is that bigger financial concerns are eating up the small factories. The gain, however, is that research is being put on a more stable and reliable basis. As regards the fuel question, three large research institutions have recently been founded (the most important being in Dresden) to advance the technique of furnace building, fuel economy, and heat application. The funds for the support of these institutions are subscribed by the factories which take up the membership. Another tendency, most strongly marked in the industry, is the concentration on the production of "quality." It arises from two causes. First, the increasing weight of direct taxation necessitates the production of greater values from the use of the same amount of capital; secondly, the individual naturally attempts to evade taxation by re-investments of earnings in the business in forms which taxation can with difficulty attack. Thus, in the porcelain factories, far more engineers, chemists, and artists are being employed to improve the quality and value of the products. In a word, the future of the industry seems to consist in far greater specialization in scientific and technical ware, and in more artistic decorative porcelain.

RESEARCH-COMBINE IN THE GERMAN PORCELAIN INDUSTRY.—(*Zeits. angew. Chem.* **34,** 435, 1921). The following concerns have combined to form a "Porcelain Manufacturers' Research Union Ltd.:—the Kahla Porcelain Works; the Hermsdorf Porcelain Works; the Freiberg Porcelain Works; the Zwickau Porcelain Works; the Königszelt Porcelain Works; the Lorenz Hutschenreuther P. Works, Selb; the Schönwald P. Works; the Arzberg P. Works; E. & A. Müller, Schönwald; Gebr. Bauscher, Weiden; the Kloster Veilsdorf P. Works; and the Rauenstein P. Works.

MENTAL FACTORS IN INDUSTRIAL ORGANIZATION.—T. T. Read (*Trans. Amer. Inst. Min. Eng., Bull.* **146,** 563, 1919). The first requisites of success in an industrial organisation are unity of purpose and coordinated activity, and these two factors are primarily mental. The paper deals with some of the reasons why the three elements in industry (capital, enterprise and labour) find it difficult to achieve the above aims.

Activity of any kind, up to the fatigue-point, is agreeable to any normal human being, if it has an adequate motive and offers an opportunity of self-expression. The functional, or so-called scientific, system of management, developed by F. W. Taylor as the best means of supervision of men of inferior grades of intelligence, has its drawbacks when applied to workmen of higher intelligence, in that it robs them almost completely of the few opportunities of self-expression in their work that remain under the modern system. The net result of the present tendency in industry is for the workman to see in his work only the unpleasant necessity of earning a living and to find his mental satisfaction in other forms of activity. The various profit-sharing schemes that have been devised are only makeshifts, and do not introduce the workman as a partner in the enterprise in the sense that his motive becomes identified with that of the organisation. Coordination of activity depends on leadership; identification of motive in industrial organisation is impossible, unless the principle is admitted that the opinions of the labouring members of the concern are entitled to a respectful hearing and consideration on their merits. In the latter part of his paper, the writer briefly discusses the relation that mental abnormalities bear to industrial organisation.

THE CONDITION AND PROSPECTS OF THE BRITISH CERAMIC INDUSTRY.—J. A. Audley (*J. Soc. Chem. Ind.*, **40,** 21 (R), 1921).

INDUSTRIAL WASTE.—Various (*Chem. Met. Eng.*, **25,** 369, 1921). A number of articles dealing with various aspects of the problem, including: Human waste in industry; Loss in production due to ill-health; Waste due to poor engineering and management; The educational waste in industry; The role of research in waste elimination; Waste due to interrupted production. The personnel problem; Disclosing waste through better cost methods; Some considerations on fire waste; Reduction of waste by accident prevention; Responsibility of owners in waste elimination; Some causes of low production; Eliminating waste and nuisance in smoke, fumes and gas; Governmental assistance in waste elimination. A further series of 26 shorter articles, featuring the outstanding causes of waste and inefficiency in the industries, has been written with great frankness by men who are fully cognizant of technical and economic conditions in their respective industries. It includes: "Production Wastes in the Ceramic Industry," by R. H. Minton; "Waste in the Glass Industry," by E. W. Tillotson; and "Cement Industry needs more Chemical Engineering," by J. G. Dean.

POTTERY MAKING IN JAPAN.—J. F. Abbott (*Clay Worker,* **73,** 596, 1920). A somewhat lengthy description of the Japanese pottery industry by the U.S. Commercial Attaché, J. F. Abbott. The numerous varieties of Japanese pottery are distinguished from one another geographically rather than technically. They may be divided into 3 classes: (1) stoneware, which is ornamental chiefly by stamping and scoring; (2) faience, generally with a crackled glazed, and highly decorated. It is not fired at so high a temperature as porcelain and is consequently softer, more fragile and more delicately coloured (3) Hard porcelain and semi-porcelain. Kaolin is mined by tun-

nelling. It is dumped from the mine on to a platform and then shovelled into a horizontal washing machine, consisting of a barrel-shaped tub filled with water, about 12 ft. long and 6 ft. in diameter. Within this barrel is a revolving horizontal shaft to which arms are attached. The quartz being heavier is deposited in a vat. The remaining kaolin and mica is then run through long troughs, which are divided into branches to retard the flow of the mixture so that the mica is allowed to float off on the surface of the water. The kaolin mixture is then run into large vats or tanks made of cement. Considerable time is allowed for settling and the surface water is then run off. The residue is pumped into iron filter presses. The kaolin leaves the presses in the form of large circular cakes, which are dried in open-air sheds or exposed to the sun. The present cost of this material at the factory is $18 per ton. The percentage of waste in the Yamaguchi district is very high, only 16% of the entire mass coming from the mine being usable. The sand washings are used to a limited extent for refractory purposes, but the great bulk is thrown away unutilized. It has been found that English kaolin must be used to obtain the finest and whitest china. It is mixed and prepared in Cornwall, and costs approx. $40 per ton delivered. The saggar clay of Japan is inferior to the American, 40% of the saggars are said to break in each firing. Most of the decorating pigments and the finest colours come largely from England, formerly from Germany. In the old style pottery the glaze is compounded of clay paste mixed with wood ashes, usually oak and chestnut. The production of chinaware is still to a large extent a domestic industry. The old-type kilns are built on the hill sides. As the industry expands, each new kiln is placed at a higher level than the preceding ones, so that the heat from the bottom passes through those above. These kilns are a crude form of the German Hoffmann system. Much of the production of the pottery villages finds its way into the channels of foreign trade. But, with labour costs rising owing to the great increase in the cost of living in Japan, the domestic industry is likely to be superceded in the near future by the highly organised modern pottery. One such pottery has been built at Nagoya, the centre of the industry. One characteristic of a modern Japanese plant is the excessive amount of manual labour employed. Labour is still by no means considered the first and greatest factor in costs. There is no railway siding; every ton of material is brought to the factory in small one-horse carts, each being led by a man. One of the newer developments is the manufacture of electrical accessories in connection with the rapidly expanding electrical industry in Japan.

THE RELATION OF THE ARTIST TO THE MANUFACTURE.—C. Dressler (*J. Am. Cer. Soc.*, **4**, 442, 1921). The achievements of the past owed their beauty to the artist. The excellent technique of the present is due to the efforts of the manufacturer and the scientist. The latter quality has now almost superceded the former; yet the esthetic needs are eternal and cannot be denied. The efforts of solitary artists are unavailing in a modern world of vast undertakings. It is for the modern factory to reintroduce the artistic spirit.

VALUING PARTLY EXHAUSTED MINES.—M. Webber (*Mining and Scientific Press*, **122**, 489, 1921). The problem is discussed mainly from the engineering point of view, but the psychology of bargaining also receives attention. The writer gives details of his experience with two copper and one gold mine. The future possibilities of a mine appear to rest on the following main factors:—(1) The total quantity of profitable ore exposed in the past without reference to what may or may not remain standing. (2) The frequency of the occurence of the shoots. (3) Did the shoots increase or decrease in size or number with depth? (4) Did the shoots assemble closer together with depth, or did they spread out, entailing additional expense in their search? (5) Did the horizontal base-line increase or decrease with depth. (6) Was the profitable nature of past operations due to secondary enrichment? If so, how far would mining operations below the present bottom be likely to continue before reaching the limit of the enriched zone?

SOME APPLICATIONS OF THE DRUM AND CABLE IN A BRICK PLANT.—R. Twells (*J. Am. Cer. Soc.*, **4**, 213, 1921). The use of the drum and cable for plowing and scraping the shale, for transferring it to the driers and out again, and for carrying the burned bricks to the freight cars is described. The devices are simple and cheap, but they have effected a great saving and have made it much easier to get the necessary labour.

THE LAY-OUT OF A BRICK OR TILE PLANT WITH A CAR TUNNEL KILN.—T. W. Garve (*J. Am. Cer. Soc.*, **4**, 277, 1921). The routing of the material (shale) and product (hollow building tiles and drain tiles) is described under the following heads: dump cars, plate feeder and crusher, storage, dry pans, screens, storage, pug mill and tile machine, combination waste heat and radiated heat drier, kiln car loading station, tunnel kiln, kiln car unloading station, stock shed. A detailed diagram is given.

V.—GLASS: GENERAL.

MOULDING GLASS BOTTLE STOPPERS.—Nelson, Ltd. and W. B. Easton (*Pat. J.*, 1697, 1921). No. 164,224, May 15, 1920. Relates to a rotary table machine for moulding glass stoppers having disk-shaped heads and taper shanks.

SEMI-AUTOMATIC BOTTLE-BLOWING MACHINE.—*J. Wolf* (*Pat. J.*, 1697, 1921). No. 164,254. Refers to machines of the rotary-table turnover parison type. Each turnover spindle, carrying a separable ring mould, is formed with an air chamber communicating with a mouth piece to which one blowpipe is applied for preliminary blowing, and another for final blowing.

BOTTLE-BLOWING MACHINE.—R. F. Hall (*Pat. J.*, 1,697, 1921). No. 164,365, Jan. 28, 1918. The blow moulds, parison moulds, and mould bottoms are carried on a travelling chain. The neck moulds and plungers are carried on an upper chain moving in unison with the lower one.

AUTOMATIC BOTTLE-BLOWING MACHINE; OWEN'S TYPE.—R. F. Hall (*Pat. J.*, 1,698, 1921). No. 164,675. Jan. 21, 1918. According to the invention, the finishing mould is mounted on a lever of the first order provided with a balance weight which slides on a bar.

CONVEYERS.—W. J. Jackson (*Pat. J.*, 1,694, 1921). No. 163,253, Sept. 1, 1919. Describes means for transferring freshly-formed glass articles from a conveyor to a leer.

ELECTRIC FURNACE FOR GLASS MANUFACTURE.—W. G. Clark (*Pat. J.*, 1,694, 1921). No. 163,267, May 11, 1921. Relates to moulding and annealing glass in an electric furnace and especially to the manufacture of lenses for astronomical telescopes.

GLASS DELIVERY TROUGHS.—W. G. Clark (*Pat. J.*, 1,696, 1927). No. 163,995, May 27, 1921. The delivery trough of a glass furnace is heated electrically by resistances connected up to leads of an electric circuit in order to facilitate starting up from cold.

GAS-FIRED GLASS FURNACE.—M. W. Travers (*Pat. J.*, 1,696, 1921). No. 164,073, Jan. 29, 1920. A chamber of increasing diameter towards the bottom is arranged beneath the eye of the furnace. Gas is supplied to the chamber through one port, and air through two others. The gas-supply channel serves to carry away glass in the event of a pot breaking.

GLASS-MELTING FURNACE.—S. G. Curd (*Pat. J.*, 1,685, 1921). No. 159,559, Nov. 20, 1919. Description of a reversible regenerative gas-fired open-hearth furnace for melting glass, etc. Two sets of gas producers are provided, one on each side of the melting-tank. The gas is superheated before entering the melting-tank.

FORMING ELECTRIC-LAMP BULBS, ETC.—Br. Thomson-Houston Co., Ltd. (*Pat. J.*, 1,685, 1921). No. 159,704, Dec. 30, 1919.

GLASS NOZZLES.—A. Kampf. (*Pat. J.*, 1,686, 1921). No. 160,168, Mar. 14, 1921. Relates to the manufacture of glass nozzles perforated with a number of fine holes for making artificial fibres. Capillary glass tubes, containing fine wires, are packed into a glass tube, which is exhausted and then heated in a rotary furnace until the glass collapses and forms a solid block embedding the wires. After cooling, the mass is cut into disks, and the wires are removed chemically.

GLASS ANNEALING FURNACE.—S. and J. E. Laycock (*Pat. J.*, 1,686, 1921). No. 160,282, Dec. 19, 1919.

BLOWING GLASS HOLLOW-WARE.—H. Fairbrother (*Pat. J.*, 1,686, 1921). No. 160,366, Apr. 6, 1920. Relates to an automatic machine, so arranged that, in charging the parison mould, the gatherer strikes a valve lever with the gathering-iron, after which all operations are automatic, including the delivery of the finished article.

SHEET-GLASS MANUFACTURE.—W. G. Clark and L. N. Bonner (*Pat. J.*, 1,687, 1921). No. 160,806, Mar. 29, 1921. Describes means of electrically heating sheets of glass whilst being drawn up from a tank of molten glass and passing to the annealing leer.

CUTTING GLASS.—Br. Thomson-Houston Co. Ltd. (*Pat. J.*, 1,688, 1921). No. 160,967, Jan. 9, 1920. Relates to a machine for cracking off the surplus necks of electric lamp bulbs.

DELIVERING MOLTEN GLASS.—British Hartford-Fairmont Syndicate and J. H. O. Bunge (*Pat. J.*, 1,688, 1921). No. 161,001, Jan. 23, 1920. Relates to a machine adapted to deliver automatically charges of molten glass to two or more machines requiring charges of different weights.

FINING GLASS.—W. G. Clark and L. N. Bonner (*Pat. J.*, 1,688, 1921). No. 161,192, Apr. 6, 1921. Describes a method of fining molten glass by applying extra heat by means of an electric current, preferably an alternating current of 60 cycles or more.

SUCTION GATHERING APPARATUS.—F. W. Howorth (*Pat. J.*, 1,689, 1921). No. 161,454, May 4, 1920. Relates to an apparatus adapted to form part of an automatic blowing machine.

SUCTION BLOWING-MACHINE.—E. Hughes and B. Wilson (*Pat. J.*, 1,691, 1921). No. 162,029, Dec. 19, 1919. The molten metal is drawn down into the neck mould by suction, a plug is withdrawn, and a puff of air is introduced whilst the turnover head is stationary.

CUTTING GLASS TUBING INTO LENGTHS.—Br. Thompson-Houston Co. (*Pat. J.*, 1,691, 1921). No. 162,037, Jan. 13, 1920. Description of apparatus in connection with glass-drawing machines.

BOTTLE-MAKING MACHINE.—M. Meunier (*Pat. J.*, 1,691, 1921). No. 162,193, May 8, 1920. Relates to a machine for making hollow glass ware, particularly champagne bottles, syphons, etc., which have to resist internal pressure.

GLASS FURNACES.—E. W. Harvey (*Pat. J.*, 1,691, 1921). No. 162,232, Sept. 16, 1920. In a gas-fired furnace heated by one or more reversible flames, supplementary ports are provided near the gathering holes, through which a portion of the heating gases is drawn, under the control of dampers, by a draught stronger than that serving the main ports.

ELECTRICALLY HEATED GLASS ANNEALING LEHRS.—E. F. Collins (*Chem. Met. Eng.*, **25**, 119, 1921). Electrically heated lehrs are successful because they supply means of automatically controlling the temperature in accordance with a predetermined cycle, whether this latter covers only a few hours or a month. This automatic control is possible within

limits of plus or minus 2·5°C. Figures are given for an oven 6 ft. 6 in. in diameter and 7 ft. 6 in. deep, showing that the maximum deviation from the mean temperature at different times during the annealing period of 72 hours varied between 2·07 and 0·35 per cent.

For annealing fine crown glass for telescopic purposes, a box type of lehr should be used. A graphic representation of the time-temperature cycle for such work is given. The control instrument is operated by a time-keeping motor supplemented by a simple cam arranged to give different ratio of heating or cooling. The advantages claimed are: (1) no opportunity for the ware to absorb products of combustion; (2) the ware is sterile and absolutely clean, which is important for medicinal purposes; (3) the low-temperature gradient which eliminates breakages, distortion, etc.

ANNEALING TEMPERATURE OF GLASS.—F. Weidert, and G. Beondt (*Zeit. Tech. Phys.*, **1**, 51, 1920).

ANNEALING OF GLASS.—L. H. Adams and E. D. Williamson (*J. Franklin Inst.*, **190**, 597, 1920).

DOUBLE REFRACTION AND CRYSTALLINE STRUCTURE OF SILICA GLASS.—Lord Rayleigh (*Proc. Roy. Soc.*, **98**, 284, 1920).

HEAT ABSORPTION IN GLASS.—A. Q. Tool and C. G. Eichlin (*J. Opt. Soc. Amer.*, **4**, 340, 1920).

DISSOLVED GASES IN GLASS.—E. W. Washburn, F. F. Footitt and E. N. Bunting (*Univ. of Ill. Eng. Expt. Sta. Bull*, No. 118, 1921).

THE COMPOSITION OF BARIUM GLASS.—R. J. Montgomery (*J. Am. Cer. Soc.*, **4**, 536, 1921). The relation between the composition of barium glasses and the optical constants is discussed, as well as the general rules for proportioning batches. The results and conclusions are given by figures (curves). The proportions cannot be so definitely expressed as in the case of lead glasses and more experience is required to enable one to change the optical properties at will.

DESIGN OF A FURNACE FOR ANNEALING OPTICAL GLASS.—D. E. Sharp (*J. Am. Cer. Soc.*, **4**, 597, 1921). Most of the furnaces built for annealing regular glassware are unsuitable for optical glass, owing to irregularity and inequalities of temperatures. Working drawings are given in this paper for a successful optical glass annealing furnace operated by natural gas. The design is novel in the placing of the flues and burners in such a manner as to supply the heat and remove it in a symmetrical manner, thus obtaining uniformity of temperature.

A SIMPLE EXPANSIBILITY TEST FOR DETERMINING THE WELDING PROPERTIES OF GLASSES.—D. E. Sharp (*J. Am. Cer. Soc.*, **4**, 219, 1921). To determine the relative expansibility of two glasses, place two rods of the glass side by side with the ends flush, heat these ends, weld together by pinching with forceps, and then pull out a thread or thin strip with the two glasses forming opposite sides. When cool the thread will bend toward the glass having the higher total expansion up to the softening point of the softer glass. This test may be used for quantitative determination of coefficients of expansion if a series of glasses of known expansibilities is available for comparison. The method is of particular value for investigating the welding properties of glasses, for whether or not two glasses can safely be welded together may be determined directly from the amount of curvature of the thread.

THE DESIGN AND OPERATION OF GLASS HOUSE FURNACES.—F. J. Denk (*J. Am. Cer. Soc.*, **4**, 224, 1921). In producer-gas furnaces, the gases being cooled should move downward and those being heated should move upward, and the dimensions should be based on actual working data.

The reversing valve should be efficient and operated regularly. The working of the furnace should be constantly watched with the help of instruments such as draft recorders and thermocouples, and the waste gases should be analysed frequently. With care in design and operation, it should be possible to approach the performance of a certain furnace which gave 3 lb. of glass for each pound of fuel burned.

ELECTRICALLY HEATED GLASS ANNEALING LEHR.—E. F. Collins (*J. Am. Cer. Soc.*, **4**, 335, 1921). Existing time-temp. data covering the relaxation of stresses in annealing of glass have been essembled. Range, control and distribution of temp. are important factors. The annealing time was reduced from 5 to 2·3 hours when the temp. var. was reduced from 10° to 2·5°C. in the case of one glass, the annealing temp. of which was 476°. Electric heat with its automatic control holds the temp. within +0·6 per cent. in ranges required for annealing, as shown by tests, even when the temp. changes 23° per hour and when, as for optical glass, the annealing treatment covers a period of one month. Electrically heated lehrs of horizontal and vertical types are discussed. The vertical lehr offers many apparent advantages and a higher thermal efficiency. A particular lehr of 500–600 lbs. ware capacity per hour, shows efficiencies in ratio of 6 to 10 in favour of electrical lehrs of the vertical type. Tests made on an electrically heated vertical lehr annealing high-grade ware showed a reduction in the cost of manufactured part of 20%, or more than 75 times the total cost of the electric power consumed.

ANCIENT AND MODERN METHODS OF GLASS MANUFACTURE.—H. L. Dixon (*J. Am. Cer. Soc.*, **4**, 85, 1921). The progress in appliances and methods of glass manufacture since 1877 is outlined. The article contains a brief summary of the personal experiences and observations of one who, for over forty years, has actively participated in the development of the glass industry.

THE MANUFACTURE AND TREATMENT OF GLASS MELTING POTS.—W. K. Brownlee and A. F. Gorton (*J. Am. Cer. Soc.*, **4**, 97, 1921). The way in which pots are made, raw materials used, etc., are briefly described, with the object of impressing glass makers with the amount of labour and care involved. At present only one grade of pot is made; but the difficulty of getting a pot suitable for all kinds of glass suggests the desirability of making special grades of pot for use with specified kinds of glass. The authors emphasize the point that the technical treatment of pots in the glass plant should be entrusted to specially trained men. The pots should be handled gently and stored in a warm, dry place. The precautions to be taken in preheating the pots in arches (the critical period in the life of the pot) are discussed at length. The batch should be properly crushed and mixed, and should either be preheated or loaded in gradually. The furnace temp. should be carefully regulated. The usual design of arches for heating glass melting-pots is discussed, and various improvements as to fire-box locations, construction of walls, door, etc., are suggested.

BOTTLE-BLOWING MACHINE.—R. F. Hall (*Pat. J.*, 1,698, 1921). No. 164,763, July 10, 1917. Relates to machines of the Owens suction type, and consists in appparatus for operating the parison moulds and closely related parts.

BOTTLE-BLOWING MACHINE.—R. F. Hall (*Pat. J.*, 1,698, 1921). No. 164,764, Seot. 19, 1917. In machines of the Owen's type, each set of parison forming and blowing mechanisms is arranged as a single unit, which can be readily removed from the machine for repair or replacement. Each unit consists of a loop-shaped frame, secured at its lower end to a ball-bearing ring, and carrying within it the parison and finishing mould-operating mechanisms.

A NEW FACTORY OF THE MONONGAH GLASS COMPANY.—E. W. Tillotson (*J. Am. Cer. Soc.*, **4**, 3, 1921). A full description of a new factory,

built in accordance with modern factory construction during the latter part of 1918, at Fairmont. All parts are correlated to bring about the most favourable conditions for the mechanical production of pressed glassware. The complete unit represents an outlay of between $700,000 and $800,000.

CEMENT, CONCRETE, MORTARS, ETC.

PAVING-CONCRETE.—C. F. Curtis (*Pat. J.*, 1,698, 1921). No. 164,666, Oct. 13, 1920. A composition suitable for flooring, paving, etc., consists of 3 parts coke breeze, 2 of sand, 3 of wood-dust, 1 of plaster of Paris or a similar setting composition, and 6 of Portland cement, with a little alum, and colouring matter according to requirements. The wood-dust and plaster of Paris are first mixed together, and the coke breeze, sand, and cement are also mixed. The two mixtures are then incorporated and gauged with water, in the last 5 gallons of which the alum is dissolved.

MANUFACTURE OF KEENE'S CEMENT.—(*Rock Products*, **24**, No. 9, 36, 1921). Keene's Cement is now produced on a large scale in America by the use of rotary kilns. The new plant, of which a sketch is given, is described in some detail. It was found that natural gypsum, treated in precisely the same manner as in the old method with stationary kilns, gave a final product by the new method which swelled very greatly in the mould, was deficient in tensile strength and density and markedly porous. The difficulty may be entirely corrected by three methods : (1) By the addition to the burnt product of a quantity of hydrate of lime, *e.g.*, from 0·2 to 0·5%; (2) By the use of a setting-agent more strongly acid than potash alum, *e.g.*, potash sulphate, containing 0·25 free acid; (3) By grinding the burnt product unusually fine, say to 150-mesh.

ARTIFICIAL STONE.—E. C. Bayer (*Pat. J.*, 1,692, 1921). No. 162,318. Diatomaceous earth is mixed with felspar or other siliceous mineral and the mixture is heated to about 1,200–1,300°C. until the felspar is fused or softened and forms a coating round the particles of diatomaceous earth. The materials may be mixed with a little water and formed into blocks. The product forms a light aggregate for concrete and may be used as a heat-insulating composition

MOULDING CONCRETE, ETC.—S. C. Carter (*Pat. J.*, 1,692, 1921). No. 162,346. Description of a turnover mould.

MOULDING MACHINE.—O. Hermoye and C. Glorian (*Pat. J.*, 1,692, 1921). Nos. 162,376 and 162,389, Jan. 26, 1920. Describes a tamping-press for forming hollow concrete blocks, with improved means for removing the block from a perforated base-plate.

MOULDING CONCRETE, ETC.—H. Willdig and J. Wood (*Pat. J.*, 1,693, 1921). No. 162,867, Mar. 4, 1920. Describes apparatus for moulding concrete blocks, bricks, pipes, etc., in which even pressure is applied simultaneously by a pressure plate throughout the entire surface of the mould.

CONCRETE BRICKS.—W. W. Crawford (*Pat. J.*, 1,693, 1921). No. 162,683, Dec. 1, 1919. Common earth, soil, clay, etc., are burnt in an oxidising atmosphere at a temperature of about 1,500°C., in an oil-burning furnace for instance, and the burnt material is mixed with a relatively small quantity of Portland or like cement previously dehydrated, preferably at about 130°C., moistened with warm water and moulded under pressure of at least 150 lbs. per sq. in. The blocks are then immersed in cold water for several hours and air-dried at a temp. slightly above freezing point.

MAKING REINFORCED CONCRETE PIPES.—B. Bradley (*Pat. J.*, 1,694, 1921). No. 163,074, Jan. 5, 1920.

MOULDING CONCRETE BLOCKS.—H. I. Hooper (*Pat. J.*, 1,695, 1921). No. 163,441, Feb. 13, 1920. Relates to presses and moulding-machines with

fixed mould tables or moulds.

BUILDING-BLOCKS, ETC.—H. Alexander (*Pat. J.*, 1,696, 1921). No. 163,746, Jan. 12, 1920. Sheets, blocks, tiles, etc., are composed of a mixture of cement, flax-fibre, a small amount of asbestos, and either silica, sand, or pumice.

ARTIFICIAL STONE.—A. Wilkinson (*Pat. J.*, 1,695, 1921). No. 163,512, Mar. 1, 1920. In the manufacture of building-blocks, etc., composed of pieces of stone, slag, brick, or other hard material held together by a cement-like binder, the mould is lined with a granular substance, such as sand, in which the hard objects are partly embedded before the binder is run in, so that they stand out in relief on the finished block. Part of the sand is taken up by the binder and ornamented effects are produced by using suitably coloured material. The binding-agent may be a mixture of cement and fine sandstone.

CONCRETE BRICKS, ETC.—D. Dale (*Pat. J.*, 1,696, 1921). No. 163,731, July 27, 1920. Building-materials such as slabs, bricks, etc., are made from a mixture of cement, sand and sawdust or wood-pulp. Suitable proportions are 1 part cement, 1 part sand and 3 parts sawdust. The cement is added to the other ingredients in 3 equal portions, and after the first 2 additions the mixture is treated with water and then allowed to become nearly dry. After the final addition of cement, sufficient water is added to produce a suitable consistency. The sawdust may be replaced by powdered clay or similar earthy material and feathers, straw, or other fibrous materials may be added. The bricks may be laid in position without mortar while in a plastic condition.

MOULDING CONCRETE PIPES.—R. Last (*Pat. J.*, 1,685, 1921). No. 159,731, Jan. 15, 1920. Relates to a tamping machine for non-circular pipes.

SHAFT FURNACE.—A. Hanenschild (*Pat. J.*, 1,685, 1921). No. 159,780, Apr. 28, 1920. In burning cement materials, magnesite, etc., the fuel and raw materials are arranged in unbroken vertical veins or columns, the fuel being surrounded on all sides by the raw materials. Preferably the fuel column is of annular form, and its top is covered, so that gases evolved are forced to pass through the raw materials. Air is supplied to the kiln through blast nozzles.

MOULDING CONCRETE BLOCKS.—Soc. Bonnet Ainé et Fils (*Pat. J.*, 1,685, 1921). No. 159,856, Oct. 23, 1920. The machine comprises a modified arrangement of parts, and means for automatically limiting the ascent of the racks.

MOULDING BRICKS, TILES, ETC.—D. Chioldi (*Pat. J.*, 1,685, 1921). No. 159,894, Mar. 7, 1921. Description of a machine for moulding bricks, etc., from cement, concrete or similar material by means of compressed air.

"RED-EARTH" CONCRETE.—F. J. Collingwood (*Pat. J.*, 1,688, 1921). No. 160,974, Jan. 13, 1920. "Devon red earth" derived from red sandstone is screened to remove stones, mixed with lime or cement, moistened with water, or moulded into bricks by manual or mechanical power and allowed to set. The bricks may have a facing of water-proofing material.

MIXING CONCRETE.—T. Lea (*Pat. J.*, 1,690, 1921). No. 161,741, Jan. 31, 1920. Description of a mixing machine, in which the cement, sand, and stones are placed in separate compartments of the hopper, from which they pass through a measuring device, a dry-mixing, and a wet-mixing device. The concrete is discharged continuously from an opening in the bottom of the pan.

WEATHER-PROOFING AND DECORATING CONCRETE, ETC.—H. C. Badder (*Pat. J.*, 1,691, 1920). No. 162,007, Oct, 22, 1919. For weather-proofing and decorating concrete or brick walls, etc., finely ground silica, to which ground glass may be added, is saturated with paraffin wax or a melted mixture of paraffin wax, fossil resins, and

asphalt, and when cool the material is ground and mixed with Portland cement and water, applied to the surface, and heated by means of a blow lamp or other means after it has set.

PLASTIC CALCINED MAGNESITE AND OXYCHLORIDE CEMENTS.—M. Y. Seaton (*Chem. Met. Eng.*, **25**, 233, 1921). An account of physical tests showing, and factors influencing, the properties of oxychloride cements. Suggested specifications include the reduction of magnesia to 97% passing 100 mesh and 75% through a 200 mesh. A chloride solution of 22 deg. Bé is used. The initial set takes from one to eight hours.

ACTION OF LIME IN MAGNESIUM OXYCHLORIDE CEMENTS.—M. T. Seaton, C. R. Hill and L. C. Stewart (*Chem. Met. Eng.*, **25**, 270. 1921). A detailed study and discussion of the action of lime impurities occurring in magnesite or magnesium oxychloride cements. Methods of determining and differentiating active from inert lime are dealt with.

THE SUCCESSFUL RECOVERY OF POTASH AS A BY-PRODUCT FROM CEMENT KILNS.—C. Kramp (*Chem. Met. Eng.*, **25**, 316, 1921). A description is given of a successful plant in which the cement dust is separated from the potash by spray washers prior to the electrical precipitation.

ANALYSIS OF PORTLAND CEMENT.—F. Ferrari (*Giorn. Chim. Ind. Appl.*, **2**, 434, 1920). A rapid and exact method is described by which the following three groups of determinations are carried out simultaneously : (1) moisture ; (2) loss on calcination, silica, alumina, lime and magnesia ; (3) insoluble silicious residue, ferric oxide and sulphuric acid. The method used for the rapid estimation of the silica is based on the practically complete insolubility of gelatinous silica with a low water content. The procedure to be followed is described in some detail. The method is applicable to the analysis of limestone, unburnt clays, etc., if these are subjected to preliminary scorification at about 1,400°C.

MIXTURES OF IRON-PORTLAND CEMENT AND NUZZUOLANA.—F. Ferrori (*Giorn. Chim. Ind. Appl.*, **2**, 549, 1920).

DISPERSOID AND COLLOID CHEMISTRY OF PLASTER.—Wo. Ostwald and P. Wolski (*Kolloid Zeits.*, **27**, 78, 1920).

LIME MORTARS : SOLUTION AND CONVERSION OF SOLID SUBSTANCES INTO COLLOIDS.—V. Kohlschütter and G. Walther (*Z. Elektrochem*, **25**, 159, 1919).

NORMAL CONSISTENCY OF SANDED GYPSUM PLASTER.—W. E. Emley and C. F. Faxon (*J. Am. Cer. Soc.*, **4**, 152, 1921). To each of a series of 12 plasters, containing various proportions of sand, 5 different amounts of water, were added, giving 5 consistencies, varying between the driest and wettest possible condition for working purposes. Two kinds of calcined gypsum and two kinds of sand were selected, and each gypsum was mixed with each sand in the proportions 1 : 1, 1 : 2 and 1 : 3, making 12 mixed plasters in all. The consistencies, determined by means of a Southard viscosimeter, and the tensile strengths of the set plasters are tabulated. The results vary both with the kind of gypsum and with the fineness of the sand. As the result of considerable experience, the authors have reached the conclusion that material of the proper consistency to be used for plastering will show a slump of $\frac{1}{2}$ inch when tested in the Southard viscosimeter.

PLASTIC MAGNESIA CEMENTS.—P. H. Bates and R. N. Young (*J. Am. Cer. Soc.*, **4**, 570, 1921). Crystalline magnesite from Washington was crushed to 3 sizes—to pass a No. 6 sieve but retained on a No. 10 ; between a No. 10 and a No. 30, and to pass a No. 60 sieve. These sizes were burned separately in an electric rotary kiln at 600°, 650, 700°, 800° and 900°C.—The cement was tested in 3 flooring mixes in which the MgO was 35·0, 42·5 or 50·0% by weight, in 3 stucco mixes in which the MgO was 11, 22 or 33% by weight. Tensile and compressive strength specimens were broken at 24 hours, 7 and 28 days. The coefficient of expansion was determined at 48

hours, 4, 7, 28 and 90 days. Other properties determined were time of set, consistency, soundness, fineness, and effect of density of the chloride solution used. *Results.* The property of the calcined cement is materially affected by the size of ore, temperature and duration of burning. The rate of reaction of MgO with chloride decreases considerably with increased temperature of burning. Decreasing the concentration of the magnesium chloride solution (down to 22° Bé) accelerates the set of freshly calcined magnesite and retards the set of magnesia which has become hydrated to a considerable extent through exposure. Exposure to moisture before using, as well as increasing the consistency of the mixture, lengthens the setting time, A composition which expands excessively and warps or buckles is not necessarily "unsound," but one which disintegrates within a comparatively short time may be considered as such. Used in this sense, "unsoundness" is believed to result from the presence of free magnesia which hydrates after the mixture has hardened, and not from the presence of lime. Therefore, soundness is not a property of the magnesia alone, but depends upon the extent to which it reacts with the magnesium chloride, water, or carbon dioxide before hardening takes place and upon the amount of hydration which subsequently occurs. The steam or cold water tests are unsatisfactory as accelerated tests for soundness of magnesia mixtures. Under the conditions of these tests, the best material with regard to setting time and strength was produced at a temperature of 800°C. However, the magnesia, burned at 650°C., which gave comparatively very low strength when gauged with at 22°Bé solution of magnesium chloride, gave excellent strengths when gauged with more concentrated solutions. Materials tested with 22° Bé solution, giving satisfactory results, would not necessarily be satisfactory with a higher or lower concentration. It seems that general specifications should also include limits corresponding with tests in which higher and lower concentrations are used. No relation was found between the volume change and any other property of magnesia. Tests of any particular mixture are no indication of the behaviour of the same magnesia in other mixtures. However, the laboratory tests indicate that the leaner mixtures undergo less change in volume than the richer ones. Furthermore, a number of strict comparisons between laboratory and field tests show that the laboratory tests of volume changes, as made, are no index to the behaviour of the material in actual service. The lean mortar mixture proved to be the most suitable of any used for testing magnesia, and in this case the tensile strength furnished as much, if not more, information than the compressive strength.

VII.—CHEMICAL AND ANALYTICAL PROCESSES.

RETORT-STANDS.—(*Zeits. angew. Chem.* **34,** 429, 1921). In a report issued by a Commission on the Standardization of Chemical Apparatus, two forms of retort-stands are recognised : (*A*) the iron-plate type, and (*B*) the "tripod" type. In the former, the base plate is made in 3 sizes, viz. : (*a*) 100 × 150 mm., (*b*) 130 × 230 mm., and (*c*) 150 × 300 mm., and the rods in four lengths : (*a*) 500 mm., (*b*) 700 mm., (*c*) 1,000 mm., (*d*) over 1,000 mm. Rod (*a*) has a diameter of 10 mm., (*b*) and (*c*) 13 mm., and (*d*) 16 mm. The centre of the hole bored into the plate to receive the rod should be 25 mm. from the edge ; in sizes (*a*) and (*b*) the hole should be in the centre of the short side, but in size (*c*) it may also be placed in the centre of the long side or in the centre of the plate. The thickness of the plate is not definitely prescribed. It should be raised from the table, so as not to come into contact with liquids, by means of four feet at the corners, measuring 10 mm. in diameter and 4 to 5 mm. in thickness. The "tripod" type of stand is made in two forms, (1) with ordinary, and (2) with strengthened feet. The central cup should be kept as low as possible, to increase the stability. Two lengths of foot-projection are given, (*a*) 95 mm., and (*b*) 115 mm. The "clump-foot" type of tripod is made in the same sizes but gives greater stability.

THE RADIATION AND CONVECTION FROM A HEATED WIRE IN AN ENCLOSURE OF AIR.—T. Barratt (*Proc. Phys. Soc.*, **28**, 1, 1915). The abrupt fall of temperature caused by the thermal resistance at the slightly conical junction of two solids was examined, the method consisting in constructing a "double joint," thus doubling also the thermal resistance effect. In the case of thin wires, the fall of temp. was found to be $2\frac{1}{2}\%$; that is, the temp. of the "hot" end of the wire is $2\frac{1}{2}\%$ lower than that of the copper block into which the end of the wire was fitted. This percentage fall of temp. is practically the same at all temperatures of the enclosure (up to 100°C.), and is independent of the excess of temp. of the end of the wire above that of the enclosure (at any rate up to 10 or 12°C.). For wires of greater diameter (6 mm.) the resistance is rather less than for thinner wires. The thermal resistance is probably due entirely to the thin film of air which must exist at the joint between the wire and the copper block.

RADIATION AND CONVECTION FROM HEATED SURFACES.—T. Barratt and A. J. Scott (*Proc. Phys. Soc.*, **32**, 361, 1920). The relative and absolute amounts of radiation and convection from surfaces heated to about 100°C. in air were measured as follows: steam was passed through cylinders or spheres, the surface temperature being measured by a thermo-junction. The total amount of heat lost from the surface was determined from the equivalent mass of steam condensed. This was done with the surface (*a*) "bright," (*b*) "dead-black." The relative amounts of radiation alone from these two surfaces were then found with the aid of a thermopile. If h is the total heat lost, and r_1 the radiation, per sq. cm. per second per 1°C. excess of temperature for the "black" surface; h_2 and r_2 corresponding quantities for the "bright" surface; and c the convection in each case, then if $h_1 = ah_1$, $r_1 = br_2$,

$$\frac{r_2}{h_2} = \frac{a-1}{b-1}, \quad \frac{r_1}{h_1} = \frac{b(a-1)}{a(b-1)}.$$

The numerical values of the radiation, convection and total heat are then easily calculable, and are given in tables. It is found that the amount of *convection* per sq. cm. is inversely proportional to the sq. root of the diameter of a cylinder, and to the cube root of the diameter of a sphere. The percentage of radiation to total heat emitted is given in the following table:—

Surface	Diameter cms.	Percentage of Radiation	
		Bright	Black
Cylinders ..	0·62	3·7	16·0
	1·275	6·1	26·1
	2·545	7·7	35·0
	5·12	10·1	37·1
Flat surface ..	—	10·9	39·5
Spheres	7·55	21·9	39·9
	10·07	21·2	38·9
	14·00	24·1	42·9
	16·50	24·8	43·9

ALUMINA.—M. Buchner (*Pat. J.*, 1,692, 1921). No. 162,303, Nov. 28, 1917. Aluminium hydrate is obtained in a granular easily filterable form by precipitation of the salt with five or more times the theoretical quantity of ammonia solution or liquid ammonia, or eight or more times the theoretical quantity of gaseous ammonia. Super-concentrated ammonia solution (obtained under pressure) may be used. Even a dry salt may be thus treated with gaseous ammonia, provided sufficient water of crystallisation is present to produce the hydrate or sufficient water is supplied with the ammonia gas.

SOLUBLE SILICATES.—F. J. Phillips (*Pat. J.*, 1,696, 1921). No.163,877,

Apr. 9, 1920. Soluble silicates of high silica content are prepared by dissolving silicic acid in alkali silicate solutions obtained by fusing silica and alkali, or silica, alkali, and borax, and treating the cooled and broken melt with water. The silicic acid is prepared, for example, by adding sulphuric acid to cold waterglass solution and after dialysis, is dissolved in the silicate solution by continued grinding or agitation.

ALUMINA.—H. G. Wildman (*Pat. J.*, 1,689, 1921). No. 161,310, Jan. 14, 1920. Clay is boiled with an alkaline solution preferably prepared by treating a solution of soda ash with a quantity of lime insufficient to convert all the carbonate to hydrate, and the clear liquor, after settling is drawn off. The treated clay, mixed with water and SO_2, is forced into the resulting suspension until no more is absorbed. The precipitated silica is filtered off, and the solution run into a vacuum pan fitted with closed steam coils. On heating, the aluminium sulphate is precipitated and the sulphur dioxide that is evolved simultaneously is stored for further use. The aluminium sulphite is removed, and after washing, is ignited to give alumina, the SO_2 evolved being recovered. Traces of sulphur remaining after the ignition must be washed out with dilute caustic soda. The sodium sulphite solution remaining after filtering off the aluminium sulphite, if treated with lime, yields caustic soda solution ready for treating fresh clay, and the precipitated calcium sulphite on ignition regenerates SO_2. When iron is present, the clay is heated before treating with alkali, so that it does not go into solution with the aluminium.

TITANIUM AND VANADIUM COMPOUNDS.—B. P. F. Kjellberg (*Pat. J.*, 1,685, 1921). No. 159,532, Oct. 20, 1919. Materials containing iron, titanium and vanadium are treated with an acid, such as sulphuric, to dissolve the metals, and the solution is evaporated to dryness. The residue is dissolved in water and the solution heated to precipitate the titanium, the remaining solution being evaporated to dryness. The second residue is heated to decompose the iron salt and then treated with water, with or without an acid or alkali, to dissolve the vanadium. When little titanium is present, the original material may be treated with diluted acid so as to dissolve the bulk of the iron and vanadium, leaving a titanium concentrate, which may be treated as above described to separate the titanium as a precipitate, and the remaining solution is added to that already obtained for procuring the vanadium.

SURVEY OF THE PHYSICS AND CHEMISTRY OF COLLOIDS.—Th. Svedberg (*Chem. Met. Eng.*, **24**, 23, 1921). The following factors are dealt with in this survey : Physical and chemical properties of the colloidal phase ; formation by condensation and dispersion ; symmetrical structure ; resistance to displacement in solution ; viscosity and colloidality ; aggregation and other structural changes.

INVESTIGATIONS OF CHEMICAL LITERATURE.—F. E. Barrows (*Chem. Met. Eng.*, **24**, 423, 1921). A survey of the field of chemical literature and of the various kinds of searches or investigations. Library research, use of card index, catalogues, shelf lists and general reference works, are among the subjects dealt with.

INVESTIGATIONS OF CHEMICAL LITERATURE, II.—F. E. Barrows (*Chem. Met. Eng.*, **24**, 477, 1921). This article includes suggestions for library research in public documents and the general periodical literature in English, French and German, together with periodicals covering special fields, check lists and union lists of periodicals. A third article (pp. 517), deals with patents.

DETERMINATION OF MELTING POINTS.—C. D. Carpenter (*Chem. Met. Eng.*, **24**, 569, 1921). A brief résumé of methods used and some proposed improvements for determining truer values is given. A new method of determining the melting point of potassium chlorate is outlined.

THE SEPARATION OF LIME FROM DOLOMITE.—H. G. Schurecht (*J. Am. Cer. Soc.*, **4**, 558, 1921). Magnesium carbonate in dolomite is decomposed by calcining for one hour at 800°C. Calcium carbonate is not completely decomposed until after calcination at 960°–1,040°C. for one hour. By adding sufficient H_2SO_4 to milk of dolomite to react with the lime present, a bulky precipitate of $Mg(OH)_2$ is formed, which may be partially separated from the finer $CaSO_4$ by screening through a 120-mesh sieve. The residue on the screen contains about 68·3% MgO and represents over 50% of the original $CaMgO_2$. Separation by flotation was best effected by removing the fine material from the raw dolomite and then calcining at 920°C. Wood creosote flotation oil number 400 was found best suited for this purpose. The centrates removed by flotation, however, represent only 25% of the dolomite originally treated. By a leaching and screening treatment it is possible to obtain a product containing about 80% MgO. This is superior to Canadian magnesite in MgO content. By an elutriation treatment it is possible to obtain a residue containing over 85% MgO and representing about 30% of the original dolomite. (*cf. Trans.* **17**, 116, 1917).

A MERCURY VOLUMETER.—E. F. Goodner (*J. Am. Cer. Soc.*, **4**, 288, 1921). The eight principal volumeters which have been in use during the past few years are discussed, their advantages and disadvantages being pointed out and the requisites of a satisfactory volumeter are outlined. A new volumeter, using mercury as the liquid for determining volumes, consists of a burette, which may be raised or lowered by means of a rack and pinion. A rubber tube, attached to the lower end of the burette, connects with a reservoir. This reservoir is at a fixed point, level with the bottom of the burette when raised to its highest point and is partially filled with mercury. The whole volumeter constitutes a large U tube with one movable limb—the burette. The reading is obtained by placing a briquette in the reservoir, which causes a rise in the level of the mercury in both limbs of the U tube. The burette is then lowered until the mercury has resumed its former level, the volume can then be read directly from the graduations on the burette. It is shown that a ratio of 1 : 1 of the reservoir and burette areas of the mercury surface will enable the reading of volumes to be made as accurately as one can obtain the burette reading. Mercury, water and kerosene behave alike in obtaining volumes. No saturation of burned or dry pieces is necessary with mercury. Checked with pycnometer and overflow types, the readings obtained agreed to within 0·05cc. Results of 3 operators working independently indicate that for volumes above 25·00cc. the volumeter is consistent within 0·2% which is also the accuracy of the result. *Disadvantages*:—(1) The initial cost of about 2 lb of mercury. (2) The slight tendency of the mercury to remain in cracks and holes, although it is readily shaken back into the reservoir. (3) A slight difficulty in obtaining the reading for the first dozen determinations. *Advantages*:—(1) No 12-hour soaking in kerosene is necessary for dry pieces. (2) There is no draining of pieces after immersion. (3) No draining of liquid is necessary. (4) The reading is direct. (5) It is very speedy and accurate. (6) No adjustment is necessary before each volume is taken, and, when adjustment is required, it is very quickly accomplished. (7) There is no adjusting of ground glass stoppers.

VIII.—HISTORICAL, EDUCATIONAL, INSTITUTIONS, ETC.

THE MODERN POTTERY INDUSTRY IN MALTA.—L. H. D. Buxton and A. V. D. Hort (*Man.*, **21**, 130, 1921). Pottery is made at Zeitun and Birchircara. An old and a new method are in use at the latter place. In the old method, an ancient type of wheel is used, consisting of a wooden disc set on a truncated cone of baked clay measuring about 10 cm. maximum

diameter, narrowing down to 4 or 5 cm. at the top, and about 3 cm. high. The disc is spun by hand in a clockwise direction, and is sprinkled with sand to prevent the clay from sticking. After shaping, the pot is put aside to dry, the inside and out being smoothed with a piece of wood, and when almost dry, is polished with a pebble. The more modern wheel is of the ordinary foot-manipulation type. It has been in use only about 10 years. The pottery is fired in a simple kiln, the entrance to which is bricked up during firing. Wood is used as fuel, coal being unsuitable as it gives too hot a fire. The clay vitrifies readily and therefore has to be fired slowly. Broken-up boats are often used, the salt in them giving a white colour to the finished ware. The clay used is found on the surface near Birchircara, and sea sand is mixed with it. Ornamentation is of the simplest type. Handles are always attached outside and never pushed through the walls of the pot. There are only a few workshops, and the trade at Birchircara is confined to one family. No slip wares are made on the island, but glazes are just beginning to be introduced. A list is given of the chief types of pots made, with their Maltese names.

Broken potsherds, ancient if possible, are used for making roofs. The sherds are placed on a stone slab and crushed by means of a heavy stone, about a foot thick and 2 feet long, rounded on the lower side so as to form a rocker. The crushed product is used to form the basis of a kind of concrete, and the makers say that the ancient sherds are much better for their purpose than the modern.

Abstracts.

I.—RAW MATERIALS: GENERAL.

RAW MATERIALS: OCCURRENCE, PREPARATION, ETC.

DRY PREPARATION OF CHINA CLAY ROCK.—Anti Dahl (*Sprech.*, **54**, 393, 1921). The rock must first be ground to give: (1) powdered china clay, (2) china clay in grains, (3) quartz grains, (4) felspar grains, (5) mica flakes, (6) some powdered quartz, (7) felspar, and (8) unbroken rock. The writer suggests that the experience gained in the graphite industry might be applied, with a few necessary modifications. Two dry methods of preparation are distinguished, viz: by means of (1) air and (2) centrifugal separators. To get the best results both methods might be applied. The centrifugal separator yields the following grades: Product I. which, after screening to remove mica and organic and other impurities, represents pure kaolin; Product II. which is subjected to further grinding and then passed through the air separator; Product III. consists of felspar and quartz, *i.e.* waste; Product IV. is returned to the rollers and again passed through the separator. The air separator also divides the rock into four grades: Product I. or pure china clay; Product II. contains some mica in addition to china clay and is purified by screening; Product III. is waste, consisting of quartz and felspar; Product IV. is returned to the air separator after further grinding.

THE AUSTRO-AMERICAN MAGNESITE WORKS IN RADENTHEIN.—K. Endell (*Metall Erz*, **18**, 597, 1921). The magnesite deposits are situated at a height of from 1,500 to 1,700 metres. They are mined in terraces. The raw material is easily obtained; one man can deliver, on an average, 8 tons in 10 hours. A 9-km. ropeway conveys the material to the factory situated 1,000 m. below. It is of such uniform quality that grading becomes unnecessary. Sintering is done in 8 shaft kilns and 2 rotary furnaces. The former are fired with generator gas to a temperature of about 1,600°. After leaving the shaft kilns, the sintered material is purified by being passed through magnetic separators. The smaller rotary kiln is 50 m. long and 1·80 m. diameter, with a capacity of 55 tons per 24 hours; the larger is 100 m. long, 2·85 m. diameter, and has a capacity of 200 tons per 24 hours. They are fired with coal dust, consisting of 3 parts brown coal (5,800 cal. dry) and one part hard coal. The sintering temperature of the larger rotary kiln is about 100° higher than that of the shaft furnaces. The average analysis of the sintered material gives the following result: 85-88% MgO, 1·5-2·5% CaO, 4-5% Fe_2O_3, 1-1·5% Al_2O_3 and 4-6% SiO_2. The maximum production of which the works are capable is as follows:

(*a*) Rotary Kilns—

100 m. long	200 *t.* per 24 hours.
50 m. ,, ...	55 *t.* ,, 24 ,,
(*b*) Shaft Furnaces—	
2 at 25 *t.*	50 *t.* ,, 24 hours.
6 at 20 *t.*	120 *t.* ,, 24 ,,
	425 *t.* per 24 hours.

or approximately 115,000 tons per annum.

In the manufacture of the bricks, the sintered magnesite is passed through Maxecon mills, mixed with from 5 to 7% of water, and pressed in hydraulic machines exerting a pressure of 1,000 kg/sq. cm. The bricks are then dried in chambers, after which they are fired in a tunnel oven, 120 m. long, heated by means of a Rehman generator. The hot zone of this oven reaches a temp. of 1,500-1,520°. The tunnel has a capacity of 50 wagons, each carrying

7 tons of bricks, and from 8 to 11 wagons are passed out each day, corresponding to a production of from 60 to 80 tons of bricks. For 300 workdays, this gives an annual output of 21,000 tons of bricks. The chemical analysis of the bricks corresponds to that of the sintered magnesite, since no futher additions are made. The good quality of these magnesite bricks is the product of: (1) the high sintering temperature in the rotary kiln (1,650-1,700°); (2) the high pressure (1,000 kg/sq. cm.) to which the mixture, suitably graded as regards grain-size, is submitted; and (3) the high temperature (1,500-1,520°) at which the bricks are fired in the tunnel oven. The works possess an up-to-date laboratory, in which chemical and mechanical tests are regularly carried out. In all, over 900 workmen are employed by the Austro-American Magnesite Company.

INTERIOR STORAGE IN BRICK AND TILE WORKS.—(*Rev. Mat. Constr. Trav. Pub.*, No. 144, 132B, 1921). The article gives a description with sketches of methods of storing prepared clay in silos or vats provided with automatic feeders.

ON THE METASOMATIC PROCESSES IN SILICATE ROCKS.—V. M. Goldschmidt (*Naturwissenschaften*, **10**, 145, 1922).

INDUSTRIAL MAGNESIA.—Le Guen (*Rev. Mat. Constr. Trav. Pub.*, No. 148, 5B, 1922). A short article, dealing with the use, extraction, commerce and price of magnesia.

PHYSICAL AND CHEMICAL PROPERTIES, TESTING, ETC.

REFRACTORY EARTHS.—(*Cer.*, **23**, 128, 1920). A review of a pamphlet written by M. Larchevêque.

"OSMO" CLAY.—(*Ker. Rund.*, **29**, 28, 1921). See TRANS **20**, 48 Abs. 1920. The clay is said to be very pure and its quality is maintained fairly uniformly. Its content of free alkali, however, may often lead to unpleasant results. It is now used extensively in making white ware, wall tiles and electrotechnical porcelain and earthenware. Many works in Germany are using this clay to replace English blue and ball clay. It is also said to be very suitable for making glass pots, refractory ware, grinding stones and enamels. Its special recommendations are: its uniform composition; high plasticity and purity; white firing colour, and low sintering point accompanied by great refractoriness. Its melting point is in the neighbourhood of cone 33.

SHRINKAGE IN KAOLINS AND CLAYS ON DRYING.—A. Bigot (*Compt. Rend.*, **172**, 755, 1921).

VARIATION IN VOLUME OF KAOLINS, CLAYS AND BAUXITES UNDER THE INFLUENCE OF HEAT.—A Bigot (*Compt. Rend.*, **172**, 854, 1921).

RELATION OF STRUCTURE TO FREE ALKALI IN SODIUM SILICATE SOLUTIONS.—W. Stericker (*Chem. Met. Eng.*, **25**, 61, 1921). The determination of free alkali is a matter depending on many factors. The hydrogen electrode is probably the best method, but is not satisfactory for all purposes, and there appears to be no good general method.

THE PLASTICITY OF CLAYS ACCORDING TO ROHLAND.—(*Cer.*, **23**, 167, 1920). A general résumé of Rohland's work on plasticity.

A PRACTICAL EXPLANATION OF THE SHRINKAGE OF CLAYS AND CLAY SLIPS.—C. Mira (*Rev. Mat. Constr. Trav. Pub.*, No. 138, 35B, 1921). The points brought out are essentially similar to those dealt with previously by W. Pukall (see TRANS., **19**, 150 (A), 1920).

MODERN CLAY TESTING PRACTICE.—(*Rev. Mat. Constr. Trav. Pub.*, No. 141, 81B, 1921). Taken mainly from R. F. MacMichael's paper in *Trans. Amer. Cer. Soc.*, **17**, 639, 1915.

THE INDUSTRIAL PURIFICATION OF BRICK CLAYS BY ELECTRO-OSMOSIS.—(*Rev. Mat. Constr. Trav. Pub.*, No. 146 165B, 1921). A review of the literature on the subject.

THE COLLOIDAL PROPERTIES OF CLAYS AND THEIR PRACTICAL APPLICATIONS.—(*Rev. Mat. Constr. Trav. Pub.*, No. 148, 3B, 1922). Sequel to above, taken mainly from A. Bencke's paper (TRANS., **20**, 55 (A), 1922).

"QUARTZ" AND "FLINT" IN AMERICA.—R. Rieke (*Ber. Deut. Ker. Ges.*, **2**, 168, 1921). In American publications, the word "flint" is frequently employed where "quartz" is intended. The writer tested the rapidity of the change to cristobalite in American and European raw materials by firing the finely powdered substances in a porcelain oven to about 1,430°, and noting the change in specific gravity. His results were as follows:—

Material	Raw	After one burn
Silica sand (American) ..	2·67	2·49
Quartz rock	2·66	2·49
Flint pebbles	2·57	2·28
Chalcedone	2·66	2·32
Norwegian quartz (European)	2·65	2·37
Hohenbocka sand	2·65	2·59
Flint (Germany)	2·63	2·23

II—MANUFACTURING PROCESSES:

GENERAL:

BREAKAGE FACTORS IN SILICA BRICK MANUFACTURE.—P. H. Jung (*Chem. Met. Eng.*, **26**, 214, 1922). The best rock for making silica bricks is one that is not too pure (under 99% SiO_2). It should consist of crystals which break up into sharp fragments and which are cemented together with a ground mass of granular quartz. Uniform grinding of the material is important, but it does not influence breakage so much as certain other factors. The question as to what amount of bats should be added to the mixture is as yet difficult of solution, but it is recognised that it affects breakage considerably. About 15 per cent. is the usual quantity added. Workmanship is a very important factor, and rigid inspection is essential. Uniformity of temperature in drying is also important. In one instance, 10 per cent. of breakage was found to be due to rapid heating and lack of temperature control in the driers. Although setting has much to do with breakage, it does not occupy a prominent place in a discussion of this subject. A major factor in the question of breakage is burning. Slow heating and slow cooling are essential, since silica bricks do not expand uniformly. A well-burned brick will usually have a clear ring, will measure up to standard if the amount of bats are not excessive, and will have a specific gravity below 2·36. Manufactures differ as to the method of firing. The question as to whether heavy firing (large amounts of coal at long intervals) or light firing (small amounts at shorter intervals) should be applied, will largely depend upon the character of the available fuel. In the control of the firing operations, pyrometers have not been successful in the silica brick industry, but the writer sees no reason why they should not be used, at any rate during the critical period. Some works prefer the draught gauge, but its use is open to discussion. The time of firing usually takes from 5 to 8 days, and cooling requires a similar period.

THE FINE ART OF LIME BURNING.—G. B. Wood (*Chem. Met. Eng.*, **25**, 705, 1921). The new plant of the Rockland and Rockport Lime Corporation is described, with the aid of sketches and illustrations, including the crushing plant, kilns, charging equipment, and storage and packing. Complete mechanical handling of all materials and precise technical control of all operations have been provided.

MANUFACTURE OF PRESSED PORCELAIN INSULATORS.—E. Rath (*Ker. Rund.*, **29**, 33, 1921). The shortage of coal in Germany is leading to the erection of large central electric power stations, to supply electricity both for industrial and domestic purposes. Hence the necessity of an adequate production of good insultors. High-tension insulators are thrown and turned, the waste body being usually dried and used for dry-pressing. But for the latter purpose the body need not be of such good quality; cheaper raw materials may be employed and less grinding and washing are required. After leaving the filter-press, the body is dried in small blocks, care being taken to see that these are uniformly dry throughout. They are then ground and prepared for the press by the addition of oil and water. It is a great advantage if the liquid is sprayed on to the body under pressure, so as to avoid the formation of lumps. It is a mistake to assume that the surface of the dies should be highly polished and smooth. A rough surface grips the body during pressing.

MAGNESIA BRICKS.—(*Rev. Mat. Constr. Trav. Pub.*, No. 137, 26B, 1921). Taken mainly from a paper by J. S. McDowell and R. M. Howe (*J. Amer. Cer. Soc.*, **3**, 185, 1920).

HOW TO AVOID SCALING OF DRAIN PIPES.—(*Rev. Mat. Constr. Trav. Pub.*, No. 140, 76B, 1921).

ENAMELLED BRICKS.—G. Briffe (*Rev. Mat. Constr. Trav. Pub.*, No. 141, 87B, 1921). The subject is dealt with under Materials, Methods of Manufacture, Firing, and Methods of working. A ground plan of a small installation is given.

SOME DIFFICULTIES IN THE MANUFACTURE OF ORDINARY CLAY BRICKS.—(*Rev. Mat. Constr. Trav. Pub.*, No. 143, 113B., 1921). Deals with method of manufacture, machines etc., and lay out of works.

AMERICAN METHODS OF HANDLING, DRYING AND FIRING BRICKS.—(*Rev. Mat. Constr. Trav. Pub.*, No. 144, 129B, 1921).

GROG; ITS NATURE, PREPARATION AND PROPERTIES.—F. Brick (*Rev. Mat. Constr. Trav. Pub.*, No. 144, 134B, 1921).

CERAMICS FOR THE CHEMICAL INDUSTRY.—F. Singer (*Zeits. angew. Chem.*, **34**, 270, 1921). A general account of the various products, *e.g.* stoneware, porcelain, quartz glass, etc.

COMPOUNDING AND PREPARATION OF BODIES, ETC.

TRANSLUCENCY AND REFRACTORINESS OF PORCELAIN.—T. Hertwig (*Sprech.*, **54**, 11, 1921). A lecture from the ceramic course for higher elementary students (Volkshochschule) at Gotha. In compounding body mixtures, the refractoriness can be regulated by decreasing the acid ratio and increasing the potash content. A Cone 9 body of the formula:—

$$\left.\begin{matrix}0{\cdot}65\ K_2O \\ 0{\cdot}35\ CaO,\ ZnO\end{matrix}\right\}\ 2{\cdot}8\ Al_2O_3 : 14\ SiO_2,$$

acid ratio 1 : 1·49, and a Cone 14 body corresponding to:

$$\left.\begin{matrix}0{\cdot}83\ K_2O \\ 0{\cdot}17\ CaO,\ MgO,\ FeO\end{matrix}\right\}\ 3{\cdot}59\ Al_2O_3 : 16{\cdot}36\ SiO_2,$$

acid ratio 1 : 1·38, were highly translucent and withstood the fire well. Other bodies corresponding to the formulæ

$$\left.\begin{matrix}0{\cdot}8\ K_2O \\ 0{\cdot}2\ CaO,\ ZnO\end{matrix}\right\}\ 2{\cdot}8\ Al_2O_3 : 17\ SiO_2$$

(acid ratio 1; 1·8) and

$$\left.\begin{matrix}0{\cdot}8\ K_2O \\ 0{\cdot}2\ CaO,\ ZnO\end{matrix}\right\}\ 2{\cdot}8\ Al_2O_3 : 18\ SiO_2$$

(acid ratio 1; 1·91) showed a low refractoriness.

CONE 7 PORCELAIN BODIES (FOR STAMPING.)—Hertwig-Möhrenbach. (*Sprech*, **54**, 445, 1921). A body was fired, corresponding to the formulæ :

$$\left.\begin{array}{l}0{\cdot}4624\ K_2O\\0{\cdot}0139\ MgO\\0{\cdot}4801\ CaO\\0{\cdot}0436\ FeO\end{array}\right\}\ 1{\cdot}95\ Al_2O_3 : 7{\cdot}3871\ SiO_2$$

, and containing 42% Schmidt-Retsch

$1{\cdot}0000\ R_2O$

spar, 52% Börtewitz kaolin and 6% calcite. On the basis of rational analysis the body contains: 49·47% clay-substance, 32·38% spar, 11·29% quartz and 6·86% lime. The high clay-substance content gives a rich body for stamping purposes, with a shrinkage of 15%. The biscuit body was ground for 80 hours (at 23 revs. per minute), and the glaze for 24 hours. The glaze corresponded to

$$\left.\begin{array}{l}0{\cdot}2\ K_2O\\0{\cdot}2\ MgO\\0{\cdot}6\ CaO\end{array}\right\}\ 0{\cdot}4\ Al_2O_3 : 3{\cdot}5\ SiO_2$$

The porcelain had a blueish-white colour. In general appearance it was not distinguishable from Cone 13—14 porcelains and its hardness left nothing to be desired. It was tested with a powerful electric current and found to give very satisfactory results.

ON THE UTILIZATION OF "RED SLIME" IN GLASS MAKING AND CERAMICS.—O. Lecher (*Sprech.*, **54**, 485, 1921). Red slime, a by-product in the preparation of hydrated aluminium oxide from bauxite, is put on the market by the Lautawerk (Lausitz) in powder form and sold as an iron oxide colouring agent. It contains approximately 50% Fe_2O_3, 12% SiO_2, 8% water, 9% CaO and traces of MgO and TiO_2. Trial melts gave satisfactory glasses in bright and dark green, brown, etc. It may also be used in the production of brown ware, red bricks, etc., and its price is considerably below that of pure iron oxide.

DOLOMITE IN BODIES AND GLAZES.—(*Ker. Rund.*, **29**, 112, 1921). The composition of dolomite varies, according to its origin, between 40—55% calcium carbonate and 40—55 magnesia. It is a popular substitute for lime as a flux in porcelain glazes, since the magnesia is said to prevent "smoking" of the ware. It must be remembered, however, that magnesia is a more powerful flux than lime, both in bodies and glazes. The melting point of a porcelain glaze is reduced from cone 13 to cone 12, if the calcite content is replaced by an equal weight of dolomite. White-burning dolomite is also an excellent addition to earthenware recipes.

A METHOD OF EMPLOYING BARIUM HYDRATE IN TERRA COTTA BODIES.—(*Rev. Mat. Constr. Trav. Pub.*, No. 137, 28B, 1921). See TRANS., **19**, 156 (Abs.) 1920.

SHAPING, MOULDING, DRYING, ETC.

THE ECONOMY OF MODERN GRINDING METHODS.—H. Hardinge (*Chem. Met. Eng.*, **25**, 229, 1921). A preliminary statement regarding the high cost of the obsolete grinding plant and an appeal to the manufacturer to study the fundamental principles of reduction. A classification of grinding operations is included.

NOTES ON DRYING HOLLOW OR LARGE-SIZE CLAY WARES.—(*Rev. Mat. Constr. Trav. Pub.*, No. 137, 24 B, 1921).

ARTIFICIAL DRYING OF BRICKS.—(*Rev. Mat. Constr. Trav. Pub.*, No. 143, 117 B, 1921).

BRICK SHAPES.—R. Ashworth (*Pat. J.*, 1,693, 1921). No. 162,726, Jan. 2, 1920. Solid or hollow blocks are formed with undercut grooves at their ends and grooves on top and bottom faces running into end grooves to receive grouting which binds the blocks together.

HOLLOW BRICKS.—J. H. Punchard (*Pat. J.*, 1,693, 1921). No. 162,857, Feb. 28, 1920.

TEAPOT LIDS.—W. G. Barratt, and King and Barratt Ltd. (*Pat. J.*, 1,698, 1921). No. 164,674, Nov. 30, 1920. The lid of a tea or coffee pot is retained in position during the action of pouring by the upper inner end of the handle projecting over the lid.

THE MANUFACTURE OF PORCELAIN.—M. Larchevêque (*Cer.*, **24**, 49, 1921). A series of 3 articles, being an extract from the ceramic course at l'Ecole Nationale Professionnelle de Vierzon-Ville, and dealing with the subject of contraction. Numerous calculations and diagrams are given to illustrate methods of reducing or enlarging pieces of various shapes to scale.

SYMPOSIUM ON DRYING.—(*J. Ind. Eng. Chem.*, **13**, 427, 1921). A series of 6 articles, including one on "Tunnel Dryers," by G. B. Ridley.

KILNS, OVENS, MUFFLES; FIRING TECHNIQUE, ETC.

THE PRINCIPLES OF PEAT BURNING.—(*Sprech.*, **54**, 166, 1921).

FIRING WITH COAL DUST.—(*Sprech.*, **54**, 329, 1921).

HEAT ECONOMY IN INDUSTRY.—(*Sprech.*, **54**, 341, 1921).

MODERN HEAT-SAVING METHODS.—E. Popp (*Sprech.*, **54**, 433, 1921).

IS IT NECESSARY TO PREHEAT AIR OF COMBUSTION.—(*Sprech.*, **54**, 495, 1921).

THE GASIFICATION OF PEAT AND WOOD.—B. Waeser (*Zeits. angew. Chem.*, **34**, 51, 1921).

FUEL TECHNIQUE IN AMERICA.—M. Dolch (*Zeits. angew. Chem.*, **34**, 637, 1921).

FUEL SYMPOSIUM—Various (*J. Ind. Eng. Chem.*, **13**, 14, 1921). A series of 12 articles by different writers dealing with the various aspects of fuel consumption.

THE CONTROL OF TEMPERATURE IN INDUSTRIAL OPERATIONS.—(*Chem. Eng. and Works Chemist*, **11**, 150, 1921). A description of the different instruments used, methods of standardising, etc.

THE APPLICATION OF PRODUCER GAS TO PERIODIC MUFFLE KILNS.—F. B. Ortman (*J. Am. Cer. Soc.*, **4**, 669, 1921). The installation of the Underwood system to six terra-cotta kilns at the plant of the Northwestern Terra-Cotta Company, is described. The conclusions drawn from operating data, taken from notes and reports made during a period of 6 to 8 months, are as follows: (1) Raw producer gas can be successfully applied to periodic muffle kilns. (2) There is little or no direct fuel economy over direct firing. (3) There is no labour economy unless the installation be large enough to justify mechanical coal and ash handling devices. (4) When interest on investment, depreciation and all other pertinent factors are taken into account, it is not likely that any great economy would be affected on periodic kilns over direct firing methods. The advantages, however, are:—(*a*) Somewhat better control of combustion gases and kiln temperatures; (*b*) Decided saving in kiln repair costs; (*c*) Cleaner and more orderly kiln yard; (*d*) Abatement of smoke nuisance, particularly important in large cities.

PULVERISED COAL AS A FUEL.—M. Stein (*Cer.*, **23**, 234, 1920). A short resumé of the subject, dealing in part with the results obtained in the U.S.A.

THE USE OF LIQUID FUELS FOR INDUSTRIAL PURPOSES.—M. Goutal (*Cer.*, **23**, 235, 1920). A short résumé.

THE GASIFICATION OF SOLID FUELS.—M. Boudouard (*Cer.*, **24**, 61, 1921). As the result of systemmatic experiments, B. found (1) that the reaction $2CO = CO_2 + C$ is a function of time and temperature. The speed of the reaction, which is greater at 800° than at 650°, is accelerated by the presence of metallic oxides (catalytic action). The volume of CO_2 formed

increases uniformly. (2) The reaction $CO_2+C=2CO$ presents the same characteristics, the amount of CO formed increases uniformly, and for a given temp. the reaction is limited, the limit being the same as in the preceding reaction. Some practical conclusions are drawn relative to gas-producers, blast-furnaces and cupola-furnaces. In a study of the gasification process, producer-gas, water-gas and semi-water gas are discussed, chemical equations being given to indicate the reactions taking place.

CONTINUOUS TUNNEL KILNS AT THE PLANT OF MOUNT CLEMENS POTTERY COMPANY.—C. B. Harrop (*J. Am. Cer. Soc.*, **4**, 673, 1921). Two direct-fired kilns (biscuit and glost) are placed end to end in a specially constructed kiln building 825 feet long. Both kilns are fired with soft coal, hand stoked. Three motors are required, aggregating 8½H.P. on each kiln. Hydraulic car pushers are employed. A pressure of 8,100 lbs. is required to move the 44 cars through the biscuit kiln. These cars hold 278 dozen ware each and at a 55-minute car schedule deliver over 7,200 dozen ware per day at a fuel saving of over 85% above the previous kilns at this plant. This bisque capacity is equivalent to that of thirteen 16½ ft. diameter periodic kilns which would cost more to build than the tunnel kiln.

COKE OVEN THERMAL BALANCE SHEET.—M. Berthelot (*Cer.*, **24**, 63, 1921). The following figures are given to show that excess of air reduces the temp. much more rapidly in ovens of the bee-hive type than in those with regenerators heated by coke-oven gas :—

Excess of Air	Temperature of Combustion		Waste Heat	
	Beehive	Regenerative	Beehive	Regenerative
0 per cent	1,800°	2,500°	46	34
10 ,,	1,700°	2,400°	49	36·6
20 ,,	1,600°	2,200°	51	40
50 ,,	1,450°	1,800°	65	42
100 ,,	1,180°	1,600°	85	58

Discussing the financial side of the question, B. points out that, in producing the 12 million tons of coke required by France per annum, a profit of 381 mill. francs is made on an expenditure of 2,926 mill. francs, *i.e.*, a plus value of 43% on the value of the coal.

GASIFICATION OF POWDERED COAL.—A. E. Bourcoud (*Chem. Met. Eng.*, **24**, 600, 1921). A consideration of the velocity with which reaction takes place between producer-gas and suspended carbon, the results being used for estimating a proposal for gasifying powdered coal or oil.

THE APPLICATION OF RATIONAL FIRING IN LARGE ELECTRICAL POWER STATIONS.—M. Chevrier (*Cer.*, **23**, 184, 1920).

PORCELAIN OVENS.—J. Haviland (*Cer.*, **23**, 201, 1920). The various types of furnaces for firing ceramic wares are discussed from the point of view of the circulation of the hot gases and the utilization of fuel. The problems of circulation are studied by reference to the movements of two immiscible liquids, such as petroleum and water, in a cylinder, as carried out experimentally by Groume Grzimailo. A brief account is given of the different types of fuel—solid, liquid and gaseous—together with a description of the kilns at present in use—intermittent, recuperative furnaces, tunnel ovens, and continuous or semi-continuous chamber kilns—mainly with reference to the firing of table porcelain. The writer concludes that the two types of kilns best suited to this purpose are : (1) The tunnel oven fired with gas under pressure ; and (2) the chamber oven with exterior fire grates, the preference being given to the latter.

METHODS FOR TESTING DUTCH TILE STOVES.—K. Brabbée (*Ber. Deut. Ker. Ges.*, **2**, 87, 1921).

ON HEAT ECONOMY IN KILN FIRING.—E. Reutlinger (*Ber. Deut. Ker. Ges.*, **2**, 123, 1921). Following on a previous report, (TRANS., **20**, 70 (A) R. gives further details of the work of the Kiln Section of the German Ceramic Society. In addition to correcting individual defects, an attempt has been made to fix standards for fuel consumption, duration of firing, and above all for normal firing processes. For earthenware and porcelain, considerable progress has already been made in this direction. The smoking period, for instance, can be very considerably reduced, without affecting the quality of the ware. This point has been definitely settled with regard to wall tiles and earthenware. It has been shown conclusively that both the biscuit and the glost fire can be conducted throughout with an oxidising flame. Several porcelain ovens for thin ware were also fired from beginning to end with a decidedly oxidising atmosphere. Where more or less lengthy smoking periods are necessary in firing earthenware, this would appear to be due to faulty kiln construction and not to the demands of the ware itself. In order to decide the all-important question as to what extent the ware itself requires a reducing action, the Kiln Section has installed a number of small testing furnaces, in which definitely oxidising and reducing conditions can be maintained at will. Several curves are given, three showing typical values for temperature and the CO_2 content in various parts of the kilns and in the stack; and two typical temperature curves for porcelain ovens.

ON THE GASIFICATION OF LIGNITE.—O. Wolff (*Sprech.*, **54**, 87, 1921).

THE "PROTOS" MUFFLE KILN.—(*Sprech.*, **54**, 125, 1921). The muffle is built up of separate, interchangeable plates of thin refractory material. The "Protos" is a semi-gas kiln, in which a temp. of 1,100° can be attained with a 20-metre stack, or 1,200° with air-blast. The fuel forms a thick layer in the grate, so that stoking is only required at long intervals, when no reduction of temperature takes place. The fuel burns at the bottom only, immediately above the grating; the CO_2 thus formed penetrates through the upper fuel layers and takes up carbon, forming CO. The combustion of this gas is brought about by introducing auxiliary air (preheated by passing through flues in the kiln walls) into the furnace immediately below the muffle. The flames first pass upwards round the fore part of the muffle, and are then drawn to the rear and downwards, round the rear half of the muffle.

A FEW OBSERVATIONS ON "SMOKING".—(*Rev. Mat. Constr. Trav. Pub.*, No. 140, 73B, 1921).

NOTES ON TUNNEL KILNS.—(*Rev. Mat. Constr. Trav. Pub.*, No. 140, 75B, 1921).

COMPARISON BETWEEN AN ANNULAR AND ZIG-ZAG KILN.—(*Rev. Mat. Constr. Trav. Pub.*, No. 143, 119B, 1921).

FIRING BRICKS AND TILES WITH LIGNITE GAS.—(*Rev. Mat. Constr. Trav. Pub.*, No. 143, 121B, 1921).

A GAS-FIRED SHAFT FURNACE FOR THE CERAMIC INDUSTRY.—(*Rev. Mat. Constr. Trav. Pub.*, No., 144, 138B, 1921). A shaft furnace is illustrated, in which the air of combustion is preheated by waste heat from the firing zone.

THE FLAMELESS SURFACE COMBUSTION SYSTEM AND THE POSSIBILITY OF APPLYING IT TO THE CERAMIC INDUSTRY.—H. Steyer (*Ber. Deut. Ker. Ges.*, **2**, 83, 1921). At present, working data are available only from English and American sources. A number of small trial furnaces has been installed at the State Porcelain Works, Berlin. Results are to be published later.

THE CHANGE-OVER FROM HARD COAL FIRING TO LIGNITE AND BRIQUETTE FIRING.—O. Schöne (*Ker. Rund.*, **29**, 1, 1921).

ELECTRIC TESTING FURNACE.—(*Ker. Rund.*, **29**, 69, 1921).

FUELS AND COMBUSTION.—Dr. Aufhäuser (*Ker. Rund.*, **29**, 152, 1921). Paper read before the Council for Firing Technique of the German glass industry.

FUEL OIL BURNING IN VARIOUS PARTS OF THE WORLD.—A. F. Baillie (*J. Roy. Soc. Arts.*, **69**, 232, 1921).

SOME TESTING FURNACES FOR THE CERAMIC INDUSTRY IN GENERAL.—C. Mira (*Rev. Mat. Constr. Trav. Pub.*, No. 137, 17B, 1921).

NOTES ON THE NATURE OF THE ATMOSPHERE IN FIRING CERAMIC PRODUCTS.—F. Bigot (*Rev. Mat. Constr. Trav. Pub.*, No. 137 20B, 1921). Hardening (l'endurci) of a lead (minium) glaze when applied to sulphurous clays, is experienced if the firing temperature is allowed to rise too rapidly, since under these conditions SO_2 is still being evolved when the minium commences to part with some of its oxygen. This nascent oxygen leads to the formation of lead sulphate and hardening of the glaze. ($Pb_3O_4=3PbO+O$; $SO_2+O=SO_3$; $PbO+SO_3=PbSO_4$). To avoid this trouble under similar circumstances, the following points should be noted: (1) thorough ageing of clay coming from sulphurous localities; (2) during the firing, the temperature must be maintained at a dull red heat for several hours.

TECHNICAL CONSIDERATIONS FOR FIRING CERAMIC WARES IN TUNNEL OVENS.—(*Rev. Mat. Constr. Trav. Pub.*, No. 137, 21B, 1921) Taken from a paper by S. Trood, published in the *J. Amer. Cer. Soc.* **3**, 701, 1920.

BRIQUETTES MADE OF SAWDUST AND PEAT.—(*Rev. Mat. Const. Trav. Pub.*, No. 138, 34B, 1921). The shortage of coal in Germany has lead to the production of briquettes made from a mixture of sawdust and peat. The calorific value of the fuel is a little over one-half that of ordinary coal.

ON FIRING STONEWARE.—(*Rev. Mat. Constr. Tav. Pub.*, No. 140, 67B, 1921).

GLAZES, ENAMELS.

ON THE SOLUBILITY OF METALLIC OXIDES IN EARTHENWARE GLAZES.—R. Rieke and W. Paetsch (*Ber. Deut. Ker. Ges.*, **2**, 77, 1921). Four earthenware glazes, differing as widely as possible, were used: (1) for cone 09, containing 4·8% CaO, 44·9% PbO, 5·9% Al_2O_3, 36·3% SiO_2, 8·1% B_2O_3; corresponding to the formula:—

$$\left.\begin{matrix}0{\cdot}7\ PbO\\0{\cdot}3\ CaO\end{matrix}\right\}0{\cdot}2\ Al_2O_3\left\{\begin{matrix}2{\cdot}1\ SiO_2\\0{\cdot}4\ B_2O_3\end{matrix}\right.$$

(2) for cone 09, containing 8·4% K_2O, 5·6% Na_2O, 13·7% BaO, 5·1% CaO, 52·0% SiO_2 and 15·2% B_2O_3; (3) for cone 2a, containing 30·2% PbO, 4·5% CaO, 3·5% K_2O, 8·3% Na_2O, 9·0% Al_2O_3, 43·1% SiO_2 and 1·4% B_2O_3. (4) also melting at cone 2a, in actual use, containing neither lead nor boric acid. The colouring oxides used were those of cobalt, copper, nickel, iron, chromium and manganese. The approximate quantities required of each, to 100 parts of glaze, to produce a clear, cold glaze were as follows:—

	Co_2O_3	CaO	NiO	Fe_2O_3	Cr_2O_3	Mn_3O_4
Glaze 1	20—30	20—30	10—20	10—15	0·1—0·5	15—20
,, 2	50—60	50—60	20—30	30—40	3—5	30—40
,, 3	30—40	10—20	20—30	20—30	8—10	30—40
,, 4	2—4	5—6	1—2	20—30	1—3	10—20

The saturation limits connot be given precisely, since they depend upon the temperature, duration of firing , and method of cooling, which vary with

different ovens. But the table shows that the melting point of a glaze is not the main factor in determining its solvent capacities, but rather the chemical composition, in which lead oxide and boric acid exert a dominant influence. The Al_2O_3 content is also of some importance; glaze 2, containing no Al_2O_3 shows an unusually high solvent capacity. The author proceeds to discuss his results with the various oxides, which partly confirm and extend previous observations.

THE NEW MEURER ENAMEL SPRAYING APPARATUS.—(*Sprech.*, **54**, 139, 1921). The enamel mixture, in a dry, powdered form, and of the same composition as when used in muffle kilns, is sucked up from a glass cylinder and passed into a stream of air or oxygen under pressure in the "spray-pistol." It is conveyed by this means into the burner, which is fed, under pressure, with a combustible gas (hydrogen, acetyline, etc.) and oxygen. The powder is melted in the resulting flame and is driven with great force on to the surface of the object under treatment. The latter must be maintained at a suitable temperature, and this may be effected by means of a second flame from the burner. With this apparatus it is possible to obtain a firm, uniformly enamelled surface within a few seconds.

THE CAUSES AND CONTROL OF FISH SCALING OF ENAMELS FOR SHEET IRON AND STEEL.—R. R. Danielson and W. H. Souder (*J. Am. Cer. Soc.*, **4**, 620, 1921). An exhaustive investigation of this subject, extending over a period of eighteen months, was carried out by the Enamelled Metals Section of the Bureau of Standards. This paper presents measurements of the following factors and properties and their influence upon fish scaling in the case of typical single and three-coat enamels: time and temp. during melting of the frit; fusibility of the enamel; coefficient of expansion of the enamel, and of a variety of representative irons and steels up to 500°C. (accuracy about 0·1%); annealing the enamel coat after firing; chemical composition of the steels and irons; mechanical treatment (rolling, spinning, drawing, etc.) of the stock; microscopic surface structure of the stock; effect of chem. comp. upon the thermal expansion of the enamel. It was found incidentally that the formulæ of Mayer and Havas for computing the thermal expansion of enamels from their chem. composition cannot be relied upon. On the basis of exhaustive tests, the following *conclusions* have been drawn as to the causes and control of fish scaling: *Causes*:—(1) The cause of fish scaling lies in the difference of the coefficients of expansion of the enamel and the stock, that for steel being higher than for enamels, so that the latter are under a compressive stress. The factors influencing this phenomenon are as follows: (*a*) Composition of the enamel as affecting its coeff. of expansion; (*b*) Overfiring—thus volatilizing those substances which tend to keep the coefficient high; (*c*) Lack of annealing enamelled ware, the enamel coating of which is a glass and should logically be treated as such. (2) Fish scaling is due secondarily to a number of factors which may affect the strength of the enamel or its adherence to the metal: (*a*) The physical condition of the surface of the metal is influenced by drawing, spinning, cold rolling, or other mechanical treatment; (*b*) Composition of the glass as affecting its elastic strength; (*c*) Underfiring, enamel not fused to metals; (*d*) Cleanliness of the surface as regards removal of drawing compounds, grease, etc. *Remedies*: 1 (*a*) Adjusting the composition of the enamel so as to increase its coefficient, *e.g.*, by decreasing the boric acid content; (*b*) Correct firing of the enamel to avoid unnecessary volatilization of such fluxes as soda and cryolite; 2 (*a*) Adjusting enamel composition to increase its strength; (*b*) Correct firing to give proper adherence; 3. Treatment of metal to give best adhesion by (*a*) cold rolling or other suitable mechanical treatment of the untreated steel; (*b*) thorough cleaning. Fish scaling may therefore be absolutely controlled by one or more of the following methods: (1) By the development of an enamel with an expansion fitting the metal; (2) by annealing the enamelled ware; (3) by treatment of the metal (cold rolling, etc.); (4) by developing an enamel with a wide range of compressional elasticity and applying this to a metal treated as indicated.

GROUND-COATS FOR ENAMELS—WITH AND WITHOUT BORAX.—Froelich (*Sprech.*, **54**, 535, 1921).

ELASTIC GROUND-COAT MILL-FRITS.—Froelich (*Sprech.*, **54**, 586, 1921).

COLOURS, DECORATIVE PROCESSES, ETC.

COLOURS DEVELOPED BY COBALT OXIDES.—H. J. Witteveen and E. F. Farnau (*J. Ind. Eng., Chem.*, **13**, 1061, 1921). Some data are collected for the purpose of offering a hypothesis to account for the apparent erratic colour effects shown by the numerous oxides, alone, hydrated, or in physical or chemical combination with metallic oxides and fluxes.

THE CHROMATE-ALBUMEN COPYING PROCESS AS ETCHING GROUND ON GLASS, METALS, STONE, IVORY, ETC.—C. Fleck (*Sprech.*, **54**, 340, 1921). An excellent mixture is obtained with 1,000 cc. distilled water, 20 cc. ammonia (Sp. Gr. 0·96), 50 gr. albumen and 7 gr. ammonium bichromate. Hints are given as to the correct application of the process.

PLANT AND MACHINERY, ETC.

THE COLLOID MILL AND ITS USE IN THE CHEMICAL INDUSTRY.—B. Block (*Zeits. angew. Chem.*, **34**, 25, 1921). A general account of the process as worked out by H. Plauson.

THE COLLOID MILL, AND THE POSSIBILITIES OF ITS PRACTICAL APPLICATION.—H. Plauson (*Zeits. angew. Chem.*, **34**, 469, 1921).

PLATE AND FRAME FILTER PRESSES.—E. C. Alford (*J. Ind. Eng. Chem.*, **13**, 1,000, 1921). A contribution to a Symposium on Filtration, commencing on p. 976 of the journal.

AN IMPORTANT MECHANICAL INSTALLATION IN A BRICK AND TILE WORKS.—(*Rev. Mat. Constr. Trav. Pub.*, No. 144, 139 B, 1921). A general view of the installation in the works of An. Boulet, fils et Cie., Paris, is given. There are three series of machines, two for tiles and one for bricks.

MECHANICAL APPLIANCES IN CERAMIC WORKS.—U. Sauer (*Ber. Deut. Ker. Ges.*, **2**, 154, 1921). The writer describes the lay-out of machinery in reconstructing an old works, consisting of one main building, containing four ovens, and one wing, in which the mill-house, saggar-house, etc., are situated. The whole works is assumed to have become too small for an increasing production, and the rooms are so unfavourably situated that there is constant crossing of the various transport routes. Several sketches are included.

A NEW RESPIRATOR OUTFIT.—(*Sprech.*, **54**, 6, 1921). The "Lix" respirator consists of a thin leather bag and an aluminium mouth-piece. It is very light and easily adjustable.

III.—FINISHED PRODUCTS: TESTING, ETC.

SAGGAR BODIES; METHODS OF TESTING.—W. Steger (*Ber. Deut. Ker. Ges.*, **2**, 142, 1921). A review of recent literature, mainly American.

GLAZE CRACKS ON HIGH-TENSION INSULATORS.—(*Sprech.*, **54**, 235, 1921). The capacity of an insulator to resist sudden changes of weather may be tested by boiling it first in water and then suddenly immersing in cold water. If after several such tests no cracks appear in the glaze on cooling, the insulator may be said to be satisfactory.

BUNZLAU EMERGENCY CLAY COINAGE.—A. Berge (*Sprech.*, **54**, 496, 1921).

ON THE MANUFACTURE OF PLASTER MOULDS.—(*Sprech.*, **54**, 20, 1921). A résumé of G. A. Williams' paper (*Trans. Amer. Cer. Soc.*, **17**, 323, 1915).

MEISSEN PORCELAIN FOR DOMESTIC AND CHEMICAL PURPOSES.—W. Funk (*Zeits. angew. Chem.*, **34**, 127, 1921). A criticism of certain parts of A. A. Klein's paper (*Trans. Amer. Cer. Soc.*, **18**, 377, 1916; see TRANS., **16**, 96(A), 1916). From a study of the microstructure, Klein concluded that the Meissen domestic ware (onion pattern) was fired to 1,400—1,425°. Funk points out that this is about 100° too low. K's conclusions regarding the chemical ware were nearer the truth, but they do not fully represent the facts. F. is doubtful whether the onion pattern sample examined by K. was genuine Meissen ware. Unglazed porcelains are now made at Meissen, which are capable of withstanding temperatures of 1,700° and over, at the same time remaining absolutely gas-proof. Reference is made to Singer's paper (*Zeits. angew. Chem.*, **31**, 221, 1918; TRANS., **18**, 97(A), 1918).

COMMUNICATION FROM THE ELECTRIC INSULATOR INDUSTRY.—Bültemann (*Zeits. angew. Chem.*, **34**, 565, 1921). A theoretical discussion followed by a description of flash-over, the latter part being well illustrated by means of sections from cinematograph films.

ON THE DETERMINATION OF THE RESISTANCE OF CERAMIC PRODUCTS TO THE ACTION OF SOLUTIONS, PARTICULARLY OF ACIDS.—O. Kallauner and R. Barta (*Sprech.*, **54**, 301, 1921). The methods hitherto employed by the Bureau for Testing Materials (Berlin), various ceramic laboratories, and by Crämar and Bischof for determining the resistance of ceramic products to the action of chemical reagents, especially acids, are not uniform; they give relatively satisfactory results only in a few cases. For the most part they are inexact, and in some cases they do not serve the required purpose. In the opinion of the authors, the most reliable method is to determine the action of chemicals on the ground material rather than on the finished product. On the basis of a large number of experiments, the following method of testing is arrived at: The ceramic material is crushed to pass between a 900 and 1,600 mesh, thoroughly washed with distilled water, passed over the magnet to remove iron, dried at 120°C. and than well shaken up. About 1 gr. of the grains (v_1) is then boiled for one hour in 25 cc. conc.H_2SO_4 in a 200cc. Erlenmeyer flask fitted with a reflux condenser or glass funnel. The flask is then allowed to cool for 5 minutes in the air, after which it is cooled down in water and its contents carefully diluted with 50 cc. distilled water. The solution thus obtained is filtered and the solid remaining in the flask is decanted three times with 50 cc. of water. 50 cc. of 5% soda solution are then poured into the flask containing the solid residue, the whole being warmed for 15 minutes over the water-bath. The soda solution is then filtered off and the residue decanted three times with water; 20 cc. of water, acidulated with 5 drops of conc. HCl (Sp. Gr. 1·18), are poured over the residue, the whole contents of the flask being finally washed on to the filter. The grains are then washed with hot distilled water to remove traces of chlorine, the filter-paper is incinerated and the residue weighed (v_2). Loss on ignition (z) is determined in a separate test. The resistance of the material to acid reactions is then expressed by the formula: $k = \frac{v_2}{v_1 - z} \cdot 100$. The writers examined a number of materials, for which the following values for k were obtained: red bricks 83·8, grog bricks 91·42, Dinas bricks 96·2, paving bricks 89·37, stone ware tiles 96·3, and stoneware pipes (24 varieties) 94·72 (average).

FIRE TESTS OF BUILDING COLUMNS.—S. H. Ingberg, H. K. Griffin, W. C. Robinson, and R. E. Wilson (*Tech. Paper. Bur. Standards.*, No. 184, 1921). A very comprehensive report (375 pp.) on an investigation carried out for the purpose of ascertaining (1) the ultimate resistance to fire of pro-

tected and unprotected columns as used in the interior of buildings; (2) their resistance to impact and sudden cooling from hose streams when in a highly heated condition. The series consisted of 106 tests on columns, of which 91 were fire tests and 15 fire and water tests. The fire test series included (1) tests of representative types of unprotected structural steel, cast-iron, concrete-filled pipe, and timber columns; (2) tests wherein the metal was partly protected by filling the reentrant portions or interior of columns with concrete; (3) tests wherein the load-carrying elements of the columns were protected by 2-in. or 4-in. thicknesses of concrete, hollow clay tile, clay bricks, gypsum blocks, and also single or double layers of metal-lath and plaster; (4) re-inforced concrete columns with 2-in. integral concrete protection. The test columns were designed for a working load of approximately 100,000 pounds, and were placed in the chamber of a gas-fired furnace. Measurements were taken of the temp. of the furnace and test column and of the deformation of the latter due to the load and heat. In the fire and water tests the column was loaded and exposed to fire for a predetermined period, at the end of which a hose stream was applied to the heated column, the duration of the application and the pressure at the nozzle varying with the length of time the corresponding type of column withstood the regular fire tests. Detailed information is given concerning the construction of the columns, tests applied, furnace and related equipment, temperature and deformation measurements. The results obtained with all the different materials used are discussed at some length. The data is tabulated and plotted throughout. There are also numerous photographic illustrations.

THE RELATIONSHIP BETWEEN TRANSLUCENCY AND THICKNESS OF PORCELAIN SPECIMENS.—W. Steger (*Ber. Deut. Ker. Ges.*, **2**, 63, 1921). Figures obtained with four porcelain bodies, in plates varying from 1·4 to 2·9 mm. thick, are tabulated and plotted. The translucency-thickness graph is a straight line, showing that the one is inversely proportional to the other. Translucency increases as the clay substance content decreases; the ratio: translucency-clay substance content is the same for all thicknesses.

AN EXPLANATION OF THE DIMINISHED RESISTANCE OF REFRACTORIES TO LOADS AT HIGH TEMPERATURES.—C. Mira (*Rev. Mat. Constr. Trav. Pub.*, No. 137, 25 B, 1921). A short review of the literature on the subject. The writer concludes that reduced resistance (or rupture) of refractories is most commonly due to the fusion of the ingredients, and that fine grinding of the latter will simply lead to more rapid fusion. But this fusion is not of itself a sufficient explanation; molecular rearrangement of the alumina and silica is also a factor worthy of consideration.

A REVIEW OF RECENT WORK ON REFRACTORIES.—(*Rev. Mat. Constr. Trav. Pub.*, No. 145, 152 B, 1921).

THE INSULATING CAPACITY OF DIFFERENT KINDS OF WALLS.—(*Rev. Mat. Constr. Trav. Pub.*, No. 146, 168B, 1921). The Bureau of Architects and Engineers, of Zurich, has compiled some very reliable figures showing the thermal penetration in relation to the cost of construction. A comparative figure (W) for the different types of walls is obtained from:—

$$W = \frac{100}{P \times K}$$

where P = cost per square metre of wall, and K = coefficient of thermal penetration in calories per second, per sq. m., per 1°C difference in temperature. Judging from the figures given, the best type of wall is one consisting of slag and concrete, (2 cm. plaster, 12 cm. concrete, 5 cm. ground slag, 15 cm. concrete—total thickness 34 cms). W in this case = 4·41, compared with 1·69 for an ordinary brick wall 29 cm. thick.

THE CONSTITUTION OF PORCELAIN.—R. Rieke (*Ber. Deut. Ker. Ges.*, **2**, 3, 1921). A discussion of A. A. Klein's paper. (*Trans. Amer. Cer. Soc.*, **18**, 377, 1916; Trans., **16**, 96 (A), 1916).

THE WATER ABSORBING AND ACID-PROOF QUALITIES OF STONEWARE PIPES FOR DRAINAGE PURPOSES; DETERMINATION OF MORE PRECISE LIMITING VALUES AND OF THE RELATION BETWEEN THESE PROPERTIES AND THE CHEMICAL COMPOSITION. —O. Kallauner and J. Fiser (*Sprech.*, **54**, 421, 1921). Twenty-five pipes of different manufacture were examined. Three methods were applied to determine the water-absorbing properties, viz: (*a*) that prescribed by the Munich Conference 1884; (*b*) with boiling water; (*c*) under low pressure. The following limiting (m_n) and mean (p_n) values were obtained:—

Method	m_n	p_n
Munich Conference 1884	2·00—4·95%	3·29%
With boiling water	3·81—8·36%	5·94%
Under low pressure	5·72—9·61%	7·39%

The corresponding values for acid resistance properties (m_k) and (p_k) were: m_k = 89·97—98·83; p_k = 95·32. (see above). For the more important ingredients the following limiting (m_{ch}) and mean (p_{ch}) values were obtained from 13 chemical analyses:—

Ingredient	m_{ch}	p_{ch}
SiO_2	61·39—72·25%	64·96%
Al_2O_3	18·01—30·57	22·69
Fe_2O_3	1·75—10·58	5·60
TiO_2	0·29—2·01	1·23
CaO	1·10—5·10	2·83
MgO	0·18—1·82	0. 84

On the basis of their investigations on 25 different types of stoneware pipes, the writers propose the following classification with regard to waterproof and acid proof qualities:—

	Water-absorbing Capacity.		
	Method: Munich Conference 48 hours	With boiling water	Under low pressure
Class	*n*	*n*	*n*
I.	<2·5%	<5·0%	<6·5%
II.	2·5—4·0%	5·0—7·0%	6·5—8·5%
III.	>4·0%	>7·0%	>8·5%

Acid-proof quality: In Class I, k is >96; class II, k = 92-96; class III k is <92.

THE TRANSLUCENCY OF PORCELAIN.—W. Steger (*Ber. Deut. Ker. Ges.*, **2**, 9, 1921). A translucent substance, as defined by the author, is one through which light passes to a certain extent, but insufficiently to allow an object placed behind it to be perceived. A semi-transparent body, on the other hand, is one behind which an object can be seen, but only in indistinct outline. Methods of measuring translucency are described. The author used a modification of the Bouguer photometer. Two incandescent 50 candle-power lamps, adjustable along a length of 1 metre, are separated by a partition. At right angles to this is another partition having two apertures of 2 mm. diam., and the whole apparatus is so covered, that the light from the lamps can only pass out through the two apertures. The porcelain samples, of the same thickness, are placed over the apertures. One of the lamps is then moved until the two porcelain plates appear equally bright, the other lamp remaining fixed. The position of the fixed lamp should be so chosen, that the eye can readily perceive small differences in brightness. This varies with different observers. The translucency of the specimens then varies with the square of their distances from the lamps. The following

porcelains, in plates of exactly 3 mm. thickness, were tested:—

Body	Felspar	Sand	Zettlitz china clay
A	72 parts	4 parts	24 parts
B	68 ,,	4 ,,	28 ,,
C	64 ,,	4 ,,	32 ,,
D	60 ,,	4 ,,	36 ,,
E	56 ,,	4 ,,	40 ,,

The translucency decreased irregularly from *A* to *E* as is shown in the following table, in which, for purposes of comparison, the translucency of sample *A* is represented by 100:—

Body	Distance of moveable lamp (r_2) from observer in mm.			Translucency $-\frac{{r_1}^2}{{r_2}^2}$	Translucency (A = 100)	Difference (A = 100)
	Author	Dr. Rieke	Mean			
B	320	314	317	0·820	82 ± 2	18
C	247	247	247	0·498	50 ± 0	32
D	215	208	212	0·367	37 ± 2	13
E	131	134	133	0·144	14 ± 0·4	23

Distance of fixed lamp from A (r_1) = 350 mm.

ACID-PROOF FLOOR COATINGS.—E. Lauser (*Ker. Rund.*, **29**, 82, 1921). Tabulated results of tests with various acids are given, which show that stoneware tiles, vitrified and non-vitrified, are highly satisfactory for protecting floors against the action of acids.

TESTING INSULATORS IN FACTORY AND FIELD.—L. N. Crichton (*Electric J.*, **17**, 506, 1920). Details are given of the various methods of testing. Most insulator troubles are caused by cracks, which absorb moisture from the cement, thus becoming conductive. The most satisfactory way of locating such defective pieces of the disc type is by means of the megger. This method is easy and cheap, but it cannot be applied to multipart pin insulators. The "buzz-stick" method consists of using a forked stick to short-circuit each unit of the insulator. If the unit is good, a spark will be drawn from the end of the short-circuiting fork; if defective, the potential will be the same both sides of the unit and no spark will be drawn. In the spark coil test, the entire equipment is placed on the pole which carries the testing fork. The latter is placed round the insulator and the primary circuit of the induction coil is closed. If the insulator is bad, a spark will be shown at the spark gap. A pair of wireless telephone receivers, one terminal of which is connected to an antenna and the other to the ground, may also be used in testing, defective insulators giving off a peculiar scratching noise. Skilled testers are essential for this test, and it is difficult to apply.

THE CRUSHING STRENGTH OF REFRACTORY PRODUCTS AT DIFFERENT TEMPERATURES.—V. Bodin (*Cer.*, **23**, 177, 1920). See TRANS., **21**, 56, 1921.

PORCELAIN INSULATORS.—O. Boudouard (*Cer.*, **24**, 31, 1921). See TRANS., **20**, 100 (A) 1920.

THE MECHANICAL PROPERTIES OF PORCELAIN AND EXACT TESTING METHODS FOR THEIR DETERMINATION.—E. Rosenthal and F. Singer (*Ker. Rund.*, **29**, 81, 1921). The methods employed for testing the various mechanical properties are discussed. For testing the impact bending strength, the writers used a pendulum hammer of known weight which is allowed to swing from a given height. At its lowest position it comes into contact with a porcelain rod resting upon two knife edges. The size of the hammer and the cross section of the rod must be gauged so that the rod is broken at the first impact. The "follow through" of the pendulum, after breaking the rod, is then measured by means of a pointer.

IV.—MANAGEMENT, ORGANISATION, COSTING, ETC.: COMMERCIAL.

ENQUIRY INTO THE PROFIT-SHARING SCHEME.—L. Yeatman (*Cer.*, **23**, 161, 1920). The writer maintains that profit-sharing schemes, far from creating amicable relations, will only lead to further friction between employers and employed.

THE GERMAN SANITARY STONEWARE INDUSTRY.—(*Ker. Rund.*, **29**, 182, 1921).

THE MANUFACTURE OF TILES IN EAST AFRICA.—(*Bull. Imp. Inst.*, **19**, 297, 1921). Specimens of clay and sand, collected in Uganda, and of clay, shale and diatomite from Kenya Colony were recently examined at the Imperial Institute, and the results of the investigations are given in this paper. Blue clay, yellow clay and swamp sand were received from Uganda. The clays in the crude state were found to be unsuitable for tile manufacture owing to the high shrinkage (12·3 and 11·1 per cent.), but tiles of good quality were made from mixtures of washed clays and swamp sand, with a maximum of 40% of sand in the case of the blue clay and 20% in the case of the yellow clay. Good tiles can also be made from mixtures of washed clays with up to 60% of clay grog. The blue contains only 8·5% of impurities as compared with 30% in the yellow clay. A suitable firing temperature for either variety would appear to be about 1,000°C. The results with the Kenya clay (buff-coloured) were essentially similar to those obtained with the Uganda varieties. Tiles made from the shales, which contained small quantities of calcite, showed small white spots after burning. The chemical analysis showed that the clay and shale were similar in chemical composition. Two types of diatomite were examined: No. 1 containing much clay and some quartz, and No. 2, with less clay, and iron-stained in parts. The chemical analysis showed 52·15% SiO_2 and 30·48% Al_2O_3 for No. 1, and 70·37% SiO_2 and 8·38% Al_2O_3 for No. 2. A firing temperature of 900° C. was found to be suitable, no advantage being gained by firing to 990°C. Tiles made from mixtures of diatomite No. 1, and the clay or shale were both weaker and heavier than those made from diatomite No. 2. The porosity of the tiles was much higher than that of Yorkshire tile. Promising results were obtained both with lead and leadless glazing, but after salt-glazing at 1,200° the tiles came out bent and blistered, and very dark in colour.

THE SPANISH CERAMIC INDUSTRY.—(*Sprech.*, **54**, 609, 1921).

INDUSTRIAL TRAINING AND SELECTION OF PERSONNEL.—C. R. Dooley (*Chem. Met. Eng.*, **25**, 692, 1921). An analysis of some of the common shortcomings of industry and education. An outline of the basic principles underlying modern methods of selecting and training employees, together with helpful suggestions for solving personnel problems is given.

MEANS OF PREVENTING ACCIDENTS IN CLAY PITS.—(*Rev. Mat. Constr. Trav. Pub.*, No. 144, 131 B, 1921).

BRICK MANUFACTURE IN THE U.S.A.—F. Brick (*Rev. Mat. Constr. Trav. Pub.*, No. 146, 161B, 1921). .A description of some model plants.

MECHANICAL TRANSPORT IN POTTERIES.—U. Sauer (*Ber. Deut. Ker. Ges.*, **2**, 66, 1921). Notes on a few useful, and at the same time, cheaply installed appliances.

COSTS.—A SHORT STUDY OF FACTORY ECONOMICS.—A. G. Peterkin (*Chem. Mat. Eng.*, **24**, 253, 1921). The article gives a manager's point of view of the functions of, and services to be rendered by, factory costs departments. Factors of interdependence of costs, maximum net returns on groups, distribution of ledger totals, forms for recording operations, and statistics, reports and item analyses are discussed.

THE (GERMAN) MOSAIC TILE INDUSTRY.— (*Ker. Rund.*, **29**, 107, 1921).

THE POST-WAR ECONOMIC POSITION OF THE GERMAN PORCELAIN INDUSTRY.—C. Albrecht (*Ker. Rund.*, **29**, 217, 1921).

A RAPID AND ECONOMIC SYSTEM OF HANDLING BRICKS AND TILES.—(*Rev. Mat. Constr. Trav. Pub.*, No. 137, 23 B, 1921). A description of American methods, taken from the *Brick and Clay Record*.

A NEW SYSTEM OF HANDLING AND TRANSPORTING BRICKS, TILES, ETC., IN WORKS.—(*Rev. Mat. Constr. Trav. Pub.*, No. 138, 37 B, 1921). A full description of the system recently patented by Albert Hirt et Cie., Paris.

CERAMICS AS A BY-PRODUCT OF COAL MINING IN SWEDEN.—J. W. Beckman (*Chem. Met. Eng.*, **25**, 882, 1921). Coal has been mined in Skane (S. Sweden), since the fifteenth century. The coal is of more recent formation than that mined in England and Germany. Between the coal seams, which vary in thickness from 30 to 60 cm., there are clays and carboniferous slates. The clay-products manufacture is now the main operation at Höganäs. Firebricks, paving bricks, common building bricks, chemical ware, acid-proof bricks, terra-cotta products, sanitary and household wares are all manufactured. The carbonaceous shales are simply piled in the open and set on fire. They burn completely, leaving a dense and well-burned chamotte, which is very suitable for making pressed bricks, etc.

V.—GLASS: GENERAL.

THE RELAXATION TEMPERATURE OF GLASS.—(*Ker. Rund.*, **29**, 151, 1921). To remove internal stresses in glass, caused by sudden cooling in the making processes (blowing, pressing etc.) the glass must be heated to a temperature high enough to give the molecules sufficient mobility to respond to low pressures and thus, by changing their position, to lead to an adjustment of internal tension. This is called the relaxation temperature. F. Weidert and G. Berndt used the following method in their determinations: 25 mm. cubes were placed in kieselguhr in such a manner as to form double four-sided pyramids, the lower half of which was embedded; *i.e.* one diagonal of the cube was in a vertical position. The cubes are then brought to a given temperature within two hours in an electric furnace, and maintained at that temperature for a further six hours. The temperature at which the bedding material leaves a permanent impression upon the polished surfaces of the cubes is taken as the deformation temperature. Tension was measured at four points near the corners of the cubes by a modification of the Schulz method.

The following figures show that, with cubes of equal size, the relaxation temperature rises with the deformation temperature:—

Type of Glass	Side of Cube in mm.	Relaxation Temperature	Deformation Temperature
649/338	25	390	430
613/369	25	410	460
	50	400	(410)
519/604	25	430	520
516/640	25	495	605
	50	500	(565)
614/564	25	565	645

THE POSITION IN THE BELGIAN GLASS INDUSTRY.—(*Ker. Rund.*, **29**, 182, 1921).

THE GLASS-MAKER'S ART IN LEGEND AND HISTORY.—(*Sprech.*, **54**, 2, 1921).

THE BOHEMIAN GLASS INDUSTRY IN 1920.—O. Parkert (*Sprech.*, **54**, 12, 1921).

FUEL AND HEAT FIGURES IN GLASS FURNACES.—H. Maurach (*Sprech.*, **54**, 36, 1921). The thermal balance sheet for a Siemens and rotary-grate generator, coupled with a glass furnace, shows 43% loss of heat by radiation and conduction, and 12·5% of heat available for glass melting.

HOW TO FIRE GENERATORS WITH WOOD AND PEAT.—(*Sprech.*, **54**, 48, 1921).

GAS GENERATION IN GLASS FURNACES.—Schiller (*Sprech.*, **54**, 110, 1921).

PEAT IN THE GLASS INDUSTRY.—(*Sprech.*, **54**, 164, 1921).

NOTES ON THE USE OF APPARATUS FOR CONTROLLING GLASS FURNACES.—(*Sprech.*, **54**, 187, 1921). Deals with the usefulness and correct application of instruments for measuring temperature, draught, and the composition of the smoke gases.

ON YELLOW ETCHING.—L. Springer (*Sprech.*, **54**, 212, 1921). Tests were carried out on two types of glass; (1) a potassium-lime glass containing 34 parts potash, 22 lime and 100 sand (decolorizers—nickel oxide and selenium); (2) a soda-lime glass, of 32 parts soda, 20 lime and 100 sand (decolorizers as before). Two strips each of these two glasses were covered with yellow etching (*a*) rich in silver (*b*) poor in silver, and fired to cone 019. The potassium glass showed practically no coloration, whilst the soda glass assumed a distinctly yellow colour.

ON FUEL ECONOMY IN GLASS FURNACES.—H. Hermanns (*Sprech.*, **54**, 274, 1921).

THE USE OF PEAT IN GLASS FURNACES.—(*Sprech.*, **54**, 303, 1921).

STANDARDIZATION IN THE FRENCH GLASS INDUSTRY.—(*Sprech.*, **54**, 318, 1921).

IRIDESCENT AND LUSTRE EFFECTS ON GLASS BEADS, BUTTONS, ETC.—O. Schwarzbach (*Sprech.*, **54**, 369, 1921).

COPPER-RUBY GLASS.—H. Kühl (*Sprech.*, **54**, 383, 1921). A short discussion of the literature on the subject.

THE MANUFACTURE OF OPTICAL GLASS; ITS PROPERTIES, ETC.—(*Sprech.*, **54**, 422, 1921). Notes on a lecture by F. Weidert, giving a general survey of the manufacture and properties of optical glass.

THE FUEL PROBLEM IN THE RUSSIAN GLASS INDUSTRY.—L. Litinsky (*Sprech.*, **54**, 455, 1921).

NOTES ON THE UTILIZATION OF WASTE HEAT FROM GLASS-FURNACES.—(*Sprech.*, **54**, 471, 1921).

NOTES ON TECHNIQUE IN THE ANTIQUE GLASS INDUSTRY.—A. Köster (*Sprech.*, **54**, 507, 1921).

NOTES ON THE MANUFACTURE OF ARTIFICIAL FISH-SILVER.—O. Parkert (*Sprech.*, **54**, 586, 1921).

PRODUCTION COSTS IN THE BELGIAN PLATE-GLASS INDUSTRY.—(*Chem. Met. Eng.*, **25**, 618, 1921). According to a report by S. H. Cross, U.S., Commercial Attaché, it is estimated that production costs in this industry have now reached 600% of the pre-war figure. This is due not only to the increase in raw material costs and wages (now about 4 times as high as in 1914), but also to the introduction of the 8 hour day.

CORDS AND SURFACE MARKINGS IN GLASSWARE.—F. E. Wright (*J. Am. Cer. Soc.*, **4**, 655, 1921). In the manufacture of glassware, it is important to distinguish between surface markings and cords, both of which are serious defects. An optical arrangement suitable for carrying this out is shown. The glass sample is immersed in a liquid having the same refractive index and contained in a tank with parallel glass sides. The immersed sample may be viewed against a distant light with or without the aid of a

hand lens. Under these conditions, surface markings disappear altogether; cords, on the other hand, stand out more distinctly. The relative refringence of a cord compared with that of the adjacent glass can also be determined at the same time. For ordinary crown glasses, monochlorbenzene is suggested as an immersion liquid. Benzene lowers, whilst carbon bisulphide or monochlornapthalene raises its refractive index.

VI.—CEMENT, CONCRETE, MORTARS, ETC.

SPECIFICATIONS FOR THE COLOUR OF GYPSUM PLASTERS.—W. E. Emley and C. G. Faxon (*Chem. Met. Eng.*, **24**, 1,054, 1921).

ZIRCONIA CEMENTS.—M. Sheppard (*J. Am. Cer. Soc.*, **4**, 662, 1921). The effect of calcined zirconia on zirconia cement is studied. Seven refractory cements were made, their composition varying between (1) 90% crude zirconia (74% ZrO_2, 17% SiO_2) and 10% plastic clay, (2) 20% crude 70% calcined zirconia and 10% plastic clay, and (3) 75% refined zirconia (94% ZrO_2, 0·2% SiO_2), 15% crude zirconia and 10% clay. It was found that raw crude zirconia alone cannot be used satisfactorily as a cement owing to its high shrinkage. The addition of 50% or more of calcined zirconia practically eliminates this shrinkage and the cracking which accompanies it. The addition of 10% clay does not seriously reduce the refractoriness, and this quantity was used throughout in the tests. Draw trials showed that the cement became strong at 1,200°C. and it was very strong when burned to 1,700°C. Load tests on pieces at 1,500° showed that joints of these cements did not fail in any way at this temp. An industrial test of zirconia cement used as a wash for bungs in a malleable iron furnace showed that the life of a bung was increased by about 25% by the use of a zirconia wash.

BLAST FURNACE SLAG AS A BUILDING MATERIAL.—R. Grün (*Zeits. angew. Chem.*, **34**, 101, 1921).

VII.—CHEMICAL AND ANALYTICAL PROCESSES.

AN AID IN THE DETERMINATION OF SILICA.—(*Chem. Eng. and Works Chemist*, **11**, 89, 1921). Writing in *Chem. Anal.*, S. R. Scholes recommends, in estimating silica, that a small amount of methyl-orange should be added to the acid liquid before evaporation. It serves as an indicator, ensuring acidity, and also dyes the gelatinous solid as it separates from the solution. The particles thus coloured are less likely to be lost.

RESEARCH PROBLEMS IN COLLOID CHEMISTRY.—W. D. Bancroft (*J. Ind. Eng. Chem.*, **13**, 83, 1921). A list of 200 problems, compiled at the request of the Prof. H. N. Holmes, the publication of which, it is hoped, will stimulate research in colloid chemistry.

RAPID IODOMETRIC METHOD FOR DETERMINATION OF CHROMIUM IN CHROMITE.—E. Little and J. Costa (*J. Ind. Eng. Chem.*, **13**, 228, 1921). By means of the formation of the ferric-fluoride complex, an iodometric titration for dichromic acid may be easily carried out in the presence of large excesses of iron. The method has been found to be rapid, accurate and highly satisfactory with chrome iron ores.

COMPARISON OF MONOCHROMATIC SCREENS FOR OPTICAL PYROMETRY.—W. E. Forsythe (*J. Opt. Soc. Amer.*, **5**, 84, 1921).

A SIMPLE METHOD OF DETERMINING THE SODA CONTENT OF POTASH.—L. Springer (*Sprech.*, **54**, 328, 1921).

THE LIMIT OF ACCURACY IN CHEMICAL ANALYSES.—E. Selch and R. Garstenauer (*Sprech.*, **54**, 432, 1921). The writers discuss two analyses, from different laboratories, of samples of Hohenbocka glass sand, and point

out that, since even the second decimal place cannot be guaranteed in estimating the quantities of the ingredients present (with the exception of iron), it is both useless and misleading to carry the figures to three places of decimals

STANDARDIZATION OF LABORATORY APPARATUS.—H. Rabe (*Zeits. angew. Chem.*, **34**, 177, 1921).

VIII.—HISTORICAL, EDUCATIONAL, INSTITUTIONS, ETC.

A SELECTED BIBLIOGRAPHY OF BOOKS, IN THE ENGLISH LANGUAGE, DEALING WITH CERAMIC CHEMISTRY AND THE CERAMIC INDUSTRIES.—E. W. Washburn, C. W. Parmelee and R. K. Hursh (*J. Ind. Eng. Chem.*, **13**, 476, 1921).

NEW CERAMIC SCHOOL IN CANADA.—(*Chem. Met. Eng.*, **25**, 209, 1921). The University of Saskatchewan, Saskatoon, is perfecting plans for the establishment of a new ceramic department. W. G. Worcester, a graduate of the Ohio State University Ceramic department, has been appointed professor.

CERAMICS; ITS ARTISTIC ROLE IN ARCHITECTURE.—H. M. Magne (*Cer.*, **24**, 25, 1921).

THE PRACTICAL MAN IN THE CLAY INDUSTRY.—Loeser (*Ker. Rund.*, **29**, 181, 1921).

EXPERIENCES IN THE PEOPLE'S HIGH SCHOOL (VOLKSHOCHSCHULE).—A. Berge (*Sprech.*, **54**, 119, 1921).

CERAMICS.—O. Boudouard (*Cer.*, **23**, 225, 1920). The opening lecture of the ceramic course at the Conservatoire National des Arts et Métiers held on November, 5th 1920, being an account, in general terms, of ceramic technique and the relation of ceramics to other industries and to the physical sciences.

THE JAPANESE PORCELAIN INDUSTRY.—(*Ker. Rund.*, **29**, 2, 1921).

POPULAR COURSES IN CERAMICS.—C. Tostmann (*Ker. Rund.*, **29**, 44, 1921). Popular courses of lectures, intended for students with an elementary school education, were commenced in Germany about the middle of 1920. The first series was held at Gotha, by T. Hertwig-Möhrenbach, who devoted two hours per week to such subjects as kiln construction, firing technique, stoichiometry, etc. This example was next followed by the University of Bonn, at the request of a group of local workmen and officials. Without wishing to criticise the courses themselves, the writer points out that the lectures were somewhat too advanced for pupils with an ordinary elementary education.

POPULAR COURSES IN CERAMICS.—A. Herborth (*Ker. Rund.*, **29**, 131, 1921). and E. Berdel (*ibid. p.* 140). Replies to Tostmann (above).

INSTRUCTION IN CERAMICS.—(*Cer.*, **23**, 151, 1920). An extract is given of the syllabus of the industrial ceramics section of the Ecole Nationale Professionnelle "Henri Brisson."

Review.

Die Herstellung der feuerfesten Baustoffe.

By Friedrich Wernicke, Berlin, 1921.

This is a second and enlarged edition of the author's previous work: "The Manufacture of Refractory Bricks" (Die Fabrikation der feuerfesten Steine) published in 1905. It is of interest to learn from the second preface, that the author was induced to undertake the revision of his first book after having become acquainted (by accident) with the work published during the war period by Dr. Mellor, "whose investigations have corrected, and no doubt finally elucidated, our conception of clay-substance and the closely related factors of plasticity, binding-power and shrinkage of clays". Wernicke has had a lengthy experience both of the refractory industry itself and of metallurgical practice, and one of the main objects of the book is to bring about a closer co-operation between the makers and the users of refractory products. To call the attention of the German manufacturers to this important consideration, reference is made to the work which is now being carried on at the Laboratory of the Central School of Science and Technology, Stoke-on-Trent.

A general introduction is followed by sections on refractory building materials containing (1) quartz, (2) alumina, (3) carbon, (4) magnesia, and (5) dolomite, the first two of which are treated in particular detail. The book concludes with a useful chapter on the training of the technical staff, but here, as also in the introductory chapters, the author gives us details (more or less of a personal nature) of the unattractive side of his own experience, which, perhaps, might better have been omitted in a work of this nature.

On the whole the author is to be congratulated on having attained his main object, which is, as already pointed out, to bring about a better understanding between makers and users of refractory products. So far as we are aware, it is the only book which deals with this subject in a comprehensive manner. F.S.

Notices.

THE INDUSTRIAL FATIGUE RESEARCH BOARD.

The Board has issued quite a number of Reports, which may be obtained at a small charge from H.M. Stationery Office. The Second Annual Report gives a fairly complete analysis of the whole of the facts contained in its publications. Report No. 18—*An Investigation in Potters' Shops*, by H. M. Vernon and T. Bedford— is now in the press. It deals with the atmospheric conditions in potters' shops and with the efficiency of different types of kilns.

The Third International Chemistry Conference is to be held at Lyons from June 27th to July 2nd of this year. The general programme will include two meetings, specially organised by the technical men of the city.

The Second Congress on Industrial Chemistry will be held this year at Marseilles from July 2nd to July 7th. Among the general questions to be studied in detail, those dealing with the mineral, vegetable and animal resources of the French colonies and with fats, soaps, etc., will occupy a prominent position.

Abstracts.

I.—RAW MATERIALS: GENERAL.

CLAY AS AN AMPHOLYTE.—O. Arrhenius (*J. Amer. Chem. Soc.*, **44,** 521, 1922). Clays of different origin and different reaction have the same iso-electric point, and the curve obtained by plotting the rate of settling against the hydrogen-ion concentration has the same course as that of gelatin. Clay acts as an amphoteric electrolyte and can therefore combine with either acid or base. This is also shown by the buffer action of the clays.

NEW CHINA-CLAY DEPOSIT IN MISSOURI.—(*Brick*, **60,** 543, 1922). The Missouri Clay Mining Co. with a capital of 100,000 dollars has been incorporated to work 640 acres of clay land recently discovered by E. G. Doane, north of Poplar Bluff. It is not necessary to mix the clay with any other material in order to get a white body, and it also has unusual strength.

SAND.—F. G. Schultz (*Rock Prod.*, **25,** No. 7, 28, 1922). A brief account of the requirements of sand for glass and paint making, grinding, cleaning, furnace lining, etc.

COBALT AND ITS USES.—W. R. Barclay (*J. Soc. Chem. Ind.*, **41,** 167 R, 1922.

ON THE METASOMATIC PROCESSES IN SILICATE ROCKS.—V. M. Goldschmidt (*Econ. Geology*, **17,** 105, 1922).

RAW MATERIALS: OCCURRENCE, PREPARATION, ETC.

THE REMOVAL OF CLAY FROM SAND AND ROCK.—E. Shaw (*Rock Prod.*, **25,** No. 5, 23, 1922). A discussion on size of grains and interstitial spaces, or voids.

THE REMOVAL OF CLAY FROM SAND AND ROCK.—E. Shaw (*Rock Prod.*, **25,** No. 6, 31, 1922). Continuation of above. The whole theory of washing is based on the fact that: The removal of clay (or other substance) is in proportion to the removal of the water used in washing. The residual water with any particular sand naturally varies with the percentage of voids in that sand. The specific gravity of a sand must be known in calculating the residual water in the voids. The moisture in the pores (porosity) must also be allowed for.

ALUNITE DEPOSITS IN THE UNITED STATES.—R. H. Tingley (*Rock Prod.*, **25,** No. 6, 38, 1922). Alunite occurs as a pinkish-tinted spar in the Tashar Mountains of Utah. This deposit is one of the largest in the world, and of a high degree of purity. The alunite is a volcanic emission from Mt. Edna, a long extinct crater. Several companies have been formed to work these valuable deposits. The material contains 11·4% potash, 38·6 sulphuric acid, 37% alumina, and 13% water. Derivative products include: alum, sulphate of potash, caustic potash, sulphuric acid, aluminium, refractories, abrasives, and iron-free alumina.

KAOLIN IN ITALY.—(*China Rev.*, **4,** 408, 1922). A summary of the latest information published in the "Rerista del Servizio Minerario," 1921, is given. In 1919, there were 10 open pits and 13 underground, and in 1920, 15 open and 9 underground, with 115 workmen inside and 148 outside. In 1920 the production was 19,323 tonnes; imports, 21,103 and exports 47 tonnes.

SUGGESTED STANDARDS FOR MOISTURE AND GRIT IN CHINA CLAY.—J. Strachan (*China Rev.*, **4,** 411, 1922). The question is dealt with from the point of view of the paper industry. In view of the high cost of carriage and the fact that the moisture in the clay is valueless, it is suggested that a 12% moisture standard is too high, particularly for high-grade clays.

As practical standards for the maximum amount of grit allowable, the following figures are suggested : china clay for coating, not more than ·1 per cent. ; china clay for fine papers, not more than ·25% ; china clay for news, not more than 5%. Low-grade clays containing from 5 to 10% of mica should be designated commercially as "mica clays."

MINERAL PRODUCTION, PROVINCE OF QUEBEC, 1921.—(*Can. Chem. Metall.*, **6**, 119, 1922). *Felspar*: The production in 1921 was 9,723 tons valued at 78,568 dollars. The deposits of the region embracing the basins of the Lièvre and Gatineau rivers promise to give rise to a very flourishing industry Shipments of *chromium* amounted to only 1,893 tons, as compared with 10,585 tons in 1920. The production of graphite was 84,684 lbs. valued at 2,422 dollars, as compared with 31,913 dollars in 1920.

FELSPAR IN THE OTTAWA DISTRICT.—N. B. Davis (*Can. Chem. Metall.* **6**, 85, 1922). The felspar occurs in extremely coarse-grained pegmatite intrusions, generally in the form of dykes. The prevailing type is high in potash. The most outstanding deposit is known as the Derry quarry. Two representative analyses gave the following : silica 65·09–65·80 ; alumina 18·85–19·74 ; ferric oxide 0·029–0·031 ; lime 0·21-0·11 ; potash 13·42–12·32 ; soda 2·11–1·74. Practically the entire production is used in the manufacture of high tension insulators.

THE ELECTRO-OSMOTIC TREATMENT OF CLAYS.—P. M. (*Rev. Mat. Constr. Trav., Pub.*, No. 151, 49B, 1922). Taken from the *Ker. Rund.* (see p. 42, Abs.).

THE PRODUCTION AND USE OF TITANIUM OXIDE.—N. Heaton (*Chem. Trade J.*, **70**, 565, 1922). The manufacturing process as applied to the titaniferous ore found in abundance near Stravangar, Norway, is outlined. After being freed from impurities by mechanical treatment, the ore, which contains 47·5% titanium oxide, is reduced to fine powder in a ball mill. This powder is then treated with strong H_2SO_4 and heated, the resulting mass containing the soluble sulphate of iron and titanium which set into the form of a hard cake. This is pulverised in a disintegrator and extracted with water. The soln. thus obtained is concentrated to syrup consistency and treated to reduce the iron to the ferrous state. The titanium sulphate is decomposed by heating nearly to boiling point, with violent agitation, and titanic acid is precipitated as a white powder. The method of preparing the white opaque pigment for paints is discussed.

THE REMOVAL OF CLAY FROM SAND AND ROCK.—E. Shaw (*Rock Prod.*, **25**, No. 7, 40, 1922).

THE USE OF BASALT IN THE CHEMICAL INDUSTRY.—L. Drin (*Chim. Ind.*, **7**, 662, 1922). Ribe showed (1909) that basalt could be liquified and cast at a temp. of 1,300°C. If cooled suddenly, the resulting substance is jet black and extremely hard, but with suitable treatment, a substance is obtained with a cellular structure like primitive rock, but with a much finer grain. This "refined" basalt equals porcelain and glass in its insulating properties, but it has three important advantages : (1) after the passage of an electric arc, the material fuses together again immediately so that there is no permanent fracture ; (2) iron pins embedded in the material while cooling, remain firmly attached when the piece solidifies ; (3) basalt insulators are practically unbreakable. Owing to its acid-resisting qualities, and the possibility of obtaining large pieces, in various shapes, by fusing and casting, "refined" basalt may be used with advantage to replace lead, etc., for tanks, reservoirs, etc., in the chemical industry.

PHYSICAL AND CHEMICAL PROPERTIES, TESTING, ETC.

THE CONSTITUTION OF BLAST-FURNACE SLAGS.—C. Lemaire (*Ind. Chim.*, **9**, 105, 1922). The article deals, *inter alia*, with the structure and colours of slags, the influence of iron and manganese on the coloration, the microscopic structure, and the specific gravity.

CLAY FOR ROOFING TILES.—H. Hirsch (*Tonind. Ztg.*, **46**, 241, 1922). A short account of the essential properties.

DESCRIPTION OF TEST ON FURNACE SAND.—M. W. Mawhinney (*Blast Furnace and Steel Plant*, **10**, 136, 1922). The author has devised a simple test to establish a reliable comparison between the thermal conductivity of a specimen of sand and of an ordinary firebrick under identical conditions. A rough constant for practical use is arrived at.

THE MICROSCOPIC EXAMINATION OF THE MINERAL CONSTITUENTS OF SOME AMERICAN CLAYS.—H. G. Schurecht (*J. Amer. Cer. Soc.*, **5**, 3, 1922). The difference in structure of the English and American clay grains and mineral constituents was investigated under the microscope. English kaolin consists chiefly of crystalline matter, and is similar in this respect to N. Carolina kaolins. Georgia, S. Carolina, and some Pennsylvania clays consist largely of colloidal kaolin, which accounts for their difference in physical properties. It is impossible by any methods or process at present known to transform the colloidal kaolinite particles into the crystalline plate-like structure of the English china clay. The American crystalline kaolins must, therefore, be developed by better mining, blending and refining processes. But the total tonnage available from these deposits is limited, and would soon be exhausted if drawn upon intensively. The minerals present in the clays are mainly muscovite, quartz, tourmaline, biotite, zircon, alkali felspar, plagio-clase, rutile, hydrated silica and hematite.

A COMPARISON OF THE INSULATING PROPERTIES OF CERTAIN MATERIALS.—(*Rev. Mat. Constr. Trav. Pub.*, No. 151, 51 B, 1922). A translation of W. A. Hull's paper (*Amer. Bur. Stand. Tech. Paper*, 130).

THE CHARACTERISATION OF CLAYS.—N. M. Comber (*Brit. Claywr.*, **31**, No. 360, 13, 1922). The abnormal permeability of soils, the abnormal rate of evaporation from soils, and the abnormal depression of the freezing point of soil solutions, all indicate that the soil particles have a hydrophilous or emulsoid surface ; and these abnormalities are more pronounced when the percentage of clay is greater, thus indicating that the colloidal surface has some relation to the characterisation of clay. The constitutional characteristic of clay, distinguishing it from other systems of siliceous mineral particles, is that in clay the properties of the emulsoid surface outweigh those of the suspensoid "core." In silt, etc., there is a smaller and less predominating amount of emulsoid surface. The ratio of emulsoid surface to suspended core can, therefore, be used to distinguish between clay and silt, and also to determine differences between various clays. It is suggested that the fundamental difference between fat and lean clays is the higher proportion of emulsoid surface to suspensoid core in the fat clays. The fatter the clay, the greater the volume of coagulum produced by the addition of calcium hydroxide to the suspension. But this suspension is greatly increased if the suspension is first rendered alkaline with ammonia soln. before adding the calcium salt. With a very fat Halifax clay, purified by electro-osmosis, the alkaline coagulum was 150 to 200% greater than the neutral coagulum.

II—MANUFACTURING PROCESSES:

GENERAL:

CAMEOS.—W. Hannich (*Ker. Rund.*, **30**, 35, 1922). The manufacture of cameos (brooches, etc.), is now almost entirely a glass industry concern. Other raw materials used for making the small reliefs are : (1) gypsum, in crystalline form (white, yellow, redish and blueish-grey in colour) ; (2) So-called cajalith, consisting of magnesia and SiO_2. This is pure white in colour, but can be given almost any tint by suitable additions. (3) Zinc oxy-chloride produces a very hard body, which, however, is highly poisonous, and must be handled with care. The pieces are best formed in plaster moulds.

(4) The glycerine—lead oxide body is made up as follows: 5 litres conc. glycerine, 2 l. water and 5·5 kg. litharge. Anilin dyes as suitable colouring media. Natural stone is also used, as, for instance, the agates in their natural white, red, brown, and violet colours. Sometimes the background consists of agate and the figures of glass, porcelain, etc.

FIRECLAY WARE.—B. Wilde (*Ker. Rand.*, **30,** 47, 1922). The article gives a general outline of the method of manufacture.

SYNTHETIC MAGNESITE BRICKS.—(*Tonind. Ztg.*, **46,** 469, 1922). According to German Patent 335,349, by L. Altmann, Steelworks, etc., will be in a position to prepare their own magnesite. Dolomite of a good sintering quality serves as the basis of the preparation. The constituents, upon which depends the sintering quality of the dolomite, are transferred in their original state to the magnesite brick, so that the sintering capacity of the latter is identical with that of the dolomite. Special, artificial additions do not have the same effect as the sintering constituents in natural combination. The sinterable dolomite is burned until the CO_2 is expelled. The burned dolomite is then treated with magnesium salts, preferably with solutions of magnesium chloride; the lime is washed out in solution and magnesia is precipitated. Out of 100 hg. of freshly-burned sinterable dolomite, containing about 36% magnesia, approximately 85 kg. of a body are obtained which contain over 70 kg. magnesia. But not only freshly burned dolomite may be used; sinterable dolomite which has been burned previously but has long since disintegrated and become "rotten," is also very suitable; as, for instance, furnace and converter linings, even after they have become quite wet. The "sinterability" and plasticity of the body can be increased or diminished by allowing more or less of the magnesium salt to remain in the body. This does not affect the refractoriness of the product.

A NEW METHOD OF MANUFACTURING SILICA BRICKS.—(*Tonind. Ztg.*, **46,** 458, 1922). According to German Patent 345,949, by H. Koppers, satisfactory silica bricks can be made from rock quartzites without the addition of lime, which reduces the refractoriness. The approximate composition of such a quartzite is:—SiO_2 94—96·5%; Al_2O_3 2·8—4·1%; Fe_2O_3 0·18—3·1%; CaO traces; MgO 0·08—0·12%; K_2O 0·53—0·97%. For binding purposes the natural so-called crater cement is used. This is a highly refractory and very lean clay, which occurs as a volcanic deposit in the Eifel mountains. Its average composition is as follows: 90·64 SiO_2; 7·84 Al_2O_3; 0·61 Fe_2O_3; 0·24 CaO; 0·12 MgO; 0·55 K_2O. Owing to its high content of hydrated silica, this crater cement, after fine grinding and washing, produces a very plastic body, which makes a very good binder for the ground quartzite. On firing, the crator cement forms a highly refractory skeleton, and the resulting bricks exhibit great refractoriness and durability.

COMPOUNDING AND PREPARATION OF BODIES, ETC.

A LOW FIRE PORCELAIN.—C. F. Binns and T. Burdick (*J. Amer. Cer. Soc.*, **5,** 25, 1922). Pieces of the following composition were cast and then fired at about cone 02, or lower, then glazed and fired at cone 4. The result was a pleasing porcelain. Frit batch: whiting $0·32 \times 100 = 32$; nitre $0·28 \times 202 = 56·5$; borax $0·12 \times 328 = 45·8$; soda ash $0·18 \times 106 = 19$; magnesite $0·10 \times 84 = 8·4$; calcined clay $0·24 \times 222 = 53·3$; flint $1·8 \times 60 = 108$; total 322. Georgia clay 0·07 or 18 parts was added to the fritted batch.

POWDERED COKE AS A SHORTENING MATERIAL.—(*Deut. Töp. Zieg. Ztg.*, **53,** 113, 1922). Powdered coke can be obtained from the fuel residues of locomotives, etc. A mixture of 2 parts clay to 1 of fine coke gives a very short body and produces a highly porous brick. With mixtures of 4 : 1 or 6 : 1, bricks are obtained which, though lighter than ordinary bricks, cannot be considered as thoroughly porous. The bricks should be fired with a low draught.

REFRACTORY COMPOSITIONS.—E. C. R. Marks (*Pat. J.*, 1737, 1922). No. 173,436, Nov. 2, 1920. A suitable composition for crucibles, fire-bricks, retorts, muffles, tubes, etc., contains 68 parts silicon carbide, 25 parts flake or crystalline graphite, and 7 parts of flux (clay, salts, such as borax, metallic or non-metallic oxides, or sulphides), or of flux and binder (tar or molasses)—No. 176,437, Nov. 2, 1920. A second mixture consists of 60 parts of a refractory electric furnace product such as fused silica or alumina, 20 parts, flake or crystalline graphite, 12 parts binder (tar or molasses) and 8 parts flux (clay, salts, etc.). Both mixtures are moulded in the usual way and fired to about 1,000°C.

CERAMIC MIXTURES.—L. A. Cordenot (*Pat. J.*, 1,738, 1922) No. 177,160, Mar. 14, 1922. Grains of natural or artificial corundum, or composite artificial aluminates melted in the electric furnace, are incorporated in ceramic mixtures, particularly those used for insulators, sparking plugs, pulleys, switchboard plates and other electrical apparatus.

PORCELAIN.—T. H. Riddle (*Pat. J.*, 1,740, 1922). No. 177,553, Sept. 23, 1920. Kaolin, with or without ball-clay, is mixed with an alkaline flux and sillimanite, and the mixture is fired so as to produce sillimanite and a glassy matrix in which practically all the fine silica is dissolved. Alternately, the flux (mixture of alkaline-earth oxide introduced as talc, magnesite, whitening, dolomite, or the like, and clay, with or without flint) may be mixed with kaolin and alumina, which react to produce sillimanite, and the operation completed in one stage. The final product should contain 60—85% sillimanite and 1·15—3·0% of alkaline earths.

SHAPING, MOULDING, DRYING, ETC.

DRYING AND FIRING SILICA BRICKS.—(*Tonind. Ztg.*, **46**, 428, 1922). The importance of a thorough drying is emphasised. In drying kilns the temperature should be so regulated that a maximum period of 36 hours suffices. The red patches which often appear underneath the bricks, can be avoided by covering the kiln with refractory plates instead of with iron. The bricks may be dried with equal success in closed drying tunnels (Keller system) within a period of from 3 to 4 days, or longer, particularly if the waste heat from the kilns is utilised and blown in by means of fans. The temperature may vary between 80° and 100°C. If the brick has been properly dried, it will have a good "ring," and will not easily break off at the edges. Silica bricks are best fired to cones 15-16, because at this temperature (approx. 1,450°C.) the quartz is transformed into tridymite, and reaches its maximum expansion. But the particular quartzite employed plays an important part. Some quartzites produce good bricks at cone 14. The cones should preferably be placed about 5 ft. from the door on a level with the peephole. All draughts must be excluded from the kiln during cooling, as the bricks are very sensitive. For bricks weighing about 13 lbs., the grain size should be as small as possible, so as to render the product sufficiently dense.

The mistaken opinion is still held on certain works that silica bricks must be dried in a hot drying oven within about 24 hours. The red patches may also be explained as follows: The best binder for silica bricks, has been found to be milk of lime, the binding power of which is increased by the addition of the syrup-like "silikanite." These two binding media have a corrosive action on the iron plates upon which the fresh bricks are placed; rust (iron hydroxide) is formed which is absorbed by the lower portion of the brick. When the latter is quite dry, iron oxide (Fe_2O_3) is formed, hence the red coloration. But this is not the only cause. Probably no works use quartz mixtures which do not contain some free iron; and when the fresh bricks are placed in a hot drying oven, the moisture is completely expelled from the lower portions (red colour), leaving the remainder more or less moist (dirty brown colour). The bricks may be dried equally well in drying sheds, if necessary, for a period of 14 days; as regards mechanical strength they are in no way inferior to oven-dried bricks. Moreover, losses due to waste heat

and breakage are considerable in drying ovens.

The firing temperature depends upon the nature of the quartz used and the object for which the bricks are intended. Good-quality silica bricks should usually contain 3 to 5% of basic oxides ; the percentage weight of the sulphates amounts to 8-14%. In Martin furnaces, the bricks are exposed to a temp. of 1,700°C., whilst in coke ovens the degree of heat is much lower, so that, in the latter case, the basic oxide content may be twice as great. In America, silica bricks are manufactured solely from rock quartzites, and the high firing temperature (cones 16-18) ensures the necessary transformation of the quartz. The German raw materials consist almost exclusively of rock quartzites, "Findlings" quartzites and carbonaceous sandstones. The bricks are fired to cones 10-12, which is probably too low a temp. to effect the necessary quartz transformations (cone 14), and the firing period is too short.

KILNS, OVENS, MUFFLES: FIRING TECHNIQUE, ETC.

ON CONTINUOUS TUNNEL KILNS AND THE "HERDA" SYSTEM.—M. Korach (*Faenza*, **10**, 18, 1922). The Faugeron, Dressler, and Roschmann kilns are discussed. The "Herda" kiln (*Trans.*, **20**, 66 (A), 1921), is said to be not inferior to the tunnel systems. It is a combination of the continuous oven (Hoffmann, etc.), and of the intermittent circular type.

HEAT ECONOMY IN THE BRICK INDUSTRY.—Nedden (*Tonind. Ztg.*, **46**, 505, 1922) A paper read by the secretary of the Committee of Experts of the (German) State Fuel Board, before the general meeting of the Brick and Tile Manuf. Association, intended rather as a "call to action" than a detailed discussion of the subject. The aims of heat economy are : (1) to make proper choice, arrangement and utilisation of thermo-technical apparatus ; (2) to make use of the most suitable, or best obtainable fuels ; (3) to maintain constant supervision of the work ; (4) to keep complete record of all firing data. Approximately 800,000 to 900,000 cal. are required to fire 1,000 standard size bricks, *i.e.*, about 2-2½ cwt. hard coal, 7-8 cwt. raw lignite, or 4-5 cwt. peat. Good quality peat is excellent for producing the long flame and moderately high temp. required for brick burning. The importance of a careful record of temperatures is emphasised. In one case the fuel consumption per 1,000 bricks, was reduced from 16 to 9 cwts. as a result of temp. control.

BURNING LIMESTONE SMALLS.—(*Tonind. Ztg.*, **46**, 228, 1922). A description, with sketch, of the Mannstaedt furnace for burning limestone in small pieces. The furnace is a modification of the old shaft type.

NOTE ON THE INCREASED ABSORPTION OF OXYGEN BY LIGNITE AFTER MOISTENING WITH ALKALI HYDROXIDE.—von Walther and W. Bielenberg (*Brennstoff-Chem.*, **3**, 97, 1922). After treatment with an alkali, specimens of Ramsdorf coal gave the following absorbtion figures for a period of 50 minutes : extracted specimen, 16·9 cc. O_2 and raw specimen 14·4 cc. O_2 per 1 gr.

TUNNEL KILNS IN THE FINE CERAMIC INDUSTRY.—P. Buresch (*Ker. Rund.*, **30**, 23, 1922). A reply to Roschmann (above). The writer maintains that the Faugeron kiln is the only tunnel oven which has proved its industrial value during 15 years in the ceramic industry.

WASTE HEAT BOILERS.—P. St. G. Kirke (*Chem. Trade J.*, **70**, 169, 1922). The paper gives a description of the old Hopwood and of the new improved patent Spencer-Hopwood boiler. The latter may be fitted to furnaces discharging gases at very high temperatures, and are capable of evaporations up to 10,000 lb. of steam per hour. But the Kirke patent gas-fired boiler represents a further improvement. In its simplest form, it consists of a drum traversed by a number of long empty tubes, which function as combustion chambers, as mixing chambers, and as extractors of the sensible heat remaining in the products of combustion. A drum boiler of this type, measuring 7 ft. diam. by 21 ft. long, fired with

coke oven gas, evaporates 21,000 lb. of steam per hour with a suction of 4 in.; 16,000 lb. with 2½ in. suction; and 10,500 lb. with 1 in. suction.

NOTES ON SULPHUR IN HARD COAL.—Ed. Donath (*Brennstoff-Chem.*, **3**, 120, 1922). A discussion on the origin of sulphur in coal.

BURNING LIGNITE IN ANNULAR KILNS.—L. Schmelzer (*Deut. Töp. Zieg. Ztg.*, **53**, 129, 1922).

DEVELOPMENT POSSIBILITIES IN METALLURGICAL FURNACES.—G. Bulle and Rosin (*Stahl Eis.*, **42**, 529, 1922). Insulation (among other factors) is discussed from the point of view of fuel economy. Formulae are given to illustrate a method of calculating heat losses due to inadequate insulation. It is shown that, in substituting kieselguhr for grog bricks in a Cowper furnace, coal would be saved to the extent of 1,284 kg. per day, corresponding to 76% of the original consumption.

TUNNEL KILNS IN THE FINE CERAMIC INDUSTRY.—C. Roschmann (*Ker. Rund.*, **30**, 2, 1922). The patent arch form of the Faugeron system is considered by the writer to be a technical defect, which renders control more difficult. Direct firing of tunnel ovens is also a mistake. The author reconstructed a Faugeron oven, eliminating these two defects, and obtained a kiln which gave every satisfaction throughout the war period. In 1920, the A.E.G. constructed a tunnel oven fired by clean gas under pressure. The air was preheated to 800° by passing through the cooling zone, and both gas and air were completely under control. In addition, the sole was preheated strongly by a special method in the preliminary heating zone, with the surprising result that the same temperature was obtained in the bottom portions of the cars as under the arch. Cone 16 was easily reached in the sole. Still better results were obtained in two kilns built by the same firm for the Schomberg Porcelain Works. One of these is capable of dealing with 15 tons of porcelain daily. Fuel consumption has been reduced to a minimum. From these results the writer concludes that the gas-fired tunnel oven should be introduced into the fine ceramic, refractory and brick industries generally.

LIME BURNING IN THE ROTARY KILN.—A. E. Truesdell. (*Rock Prod.*, **25**, No. 6, 24, 1922). A detailed description is given of the modern lime burning process. A consideration of costs, in addition to the technical points involved, is also included. For lining the kilns, it is preferable to use silica bricks, particularly in the lower 20 ft. These bricks form a heavy glaze of 1 to 1½ in. thickness, and do not contaminate the lime. Since they are very brittle. the kiln must be heated very gradually when starting up. They have a high coefficient of expansion, so that in installing, they should be packed with a flexible, non-combustible material such as asbestos or mineral wool. This packing will also serve to reduce radiation losses.

AN AUTOMATIC STOKER FOR ANNULAR KILNS.—G. Korngiebel (*Deut. Töp. Zieg. Ztg.*, **53**, 102, 1922). Germ. Pat. 334,402. The fuel container consists of a box, closed to the outside air, and containing a spiral chute, down which the coal passes to a bucket wheel, the speed of which can be regulated. Heat rising from the kiln into the box removes the moisture from the coal.

BURNING IN A COAL-FIRED DUTCH KILN.—E. Petts (*Brick*, **60**, 533, 1922). Some practical suggestions for those not thoroughly acquainted with the method of firing the kiln.

THE PRACTICAL APPLICATION OF OPTICAL PYROMETERS.—K. Daeves (*Stahl Eis.*, **26**, 121, 1922). A paper dealing with the subject mainly from the metallurgical standpoint.

DISCHARGING APPARATUS FOR SHAFT FURNACES.—C. Engelhard (*Tonind. Ztg.*, **46**, 273, 1922). A description, with diagram, of an apparatus, patented by O. Ködder & Co., for discharging shaft kilns (for lime, etc.), fired with artificial draught.

ON FIRING BITUMINOUS CLAYS.—P. Thor (*Tonind. Ztg.*, **46,** 323, 1922). Bricks and tiles are liable to swell or "bloat" in the fire if the clay used is fat and bituminous, and insufficient shortening material has been added, and if the daily progress of the fire in an annular kiln exceeds about 5 yards. To avoid bloating, the firing zone should be marked off into four sections. In the first, the fire should not be allowed to become sufficiently intense to bring about a shrinkage of the clay. The second and longest, section should preferably not be fired at all. It is a "passive" zone in which the bituminous matter is decomposed. The third zone should still be fired cautiously, the final burn being reserved for the fourth and last section.

GROG BRICKS FOR OIL-FIRED FURNACES.—(*Tonind. Ztg.*, **46,** 400, 1922). In the German navy, the maximum temperature experienced with coal-fired furnaces varied between 1,100 and 1,200°C., whilst that obtained with oil reached 1,400—1,700°. In addition, the rise in temperature is much more rapid in the latter case, so that the refractories must be more resistant to variations in temperature. They should, therefore, contain a high percentage of clay substance, be fired to a high temperature, and be more or less dense without being brittle.

LOW-TEMPERATURE CARBONIZATION OF COAL.—J. H. Frydlender (*Rev. Prod. Chim.*, **25,** 217, 1922). A review of the present condition of the industry in England and America.

THE USE OF LIGNITE FOR ANNULAR KILNS.—L. Schmelzer (*Tonind. Ztg.*, **46,** 533, 1922).

IMPROVED METHODS OF BURNING COAL.—C. E. Hayes (*Blast Fur. Steel Plant*, **10,** 239, 1922). Certain types of coal (*e.g.*, W. Pennsylvania, Ohio, W. Virginia) burn better on chain-grate stokers when properly wet than when dry. The ash is generally much better when wet coal is used.

A NEW TUNNEL OVEN FOR BRICKS AT TONGRES (BELGIUM).—M. R. (*Rev. Mat. Constr. Trav. Pub.*, No. 151, 56 B, 1922). The kiln is 100 m. long and is capable of dealing with 50 tons of ware per day, with a fuel consumption of 1,800 kg. The trucks measure 1·5 m. by 2 m. (width) by 1·4m. (height) and carry from 2,000 to 2,500 kg. of ware. The regularity of the firing is said to be complete.

FIRING BRICKS WITH PEAT.—F. Mammen (*Deut. Töp. Zieg. Ztg.*, **53,** 158, 1922).

Patents.

PULVERULENT FUEL FURNACES.—E. C. Covert (*Pat. J.*, 1,738, 1922). No. 176,912, Dec. 22, 1920. Relates to pulverulent fuel feed apparatus, comprising a closed circuit, from which air and fuel mixture is drawn off at desired points.

CHARGING GAS PRODUCERS.—D. B. Dickson (*Pat. J.*, 1,739, 1922). No. 177,289, Jan. 11, 1921. Describes fuel-feeding mechanism which is automatically controlled by the level of the fuel in the generator, being rendered inoperative when the fuel reaches or exceeds a certain level.

TUNNEL KILN.—Woodall, Duckham & Jones, Ltd., Sir A. M. Duckham and A. T. Kent (*Pat. J.*, 1,740, 1922). No. 177,561, Oct. 29, 1920. The trucks are arranged so that the length of each is transverse to the length of the tunnel, and the baffles, which divide the tunnel into compartments, are carried on the long sides of the trucks. The baffles co-operate with flanges depending from the roof. The departments are thus kept narrow and the path taken by the heating gases is correspondingly lengthened.

TUNNEL KILN.—H. Koppers (*Pat. J.*, 1,732, 1922). No. 174,852, Jan. 10, 1921. The preliminary heating and cooling chambers slope downwards from the heating zone, the cooling and heating chambers being separated by doors.

TUNNEL KILNS.—F. S. Vernon (*Pat. J.*, 1,733, 1922). No. 175,171, Jan. 14, 1921. The kiln has two or more independent firing-zones arranged in parallel, so that the kiln can be used for two or more varieties of goods requiring different treatment.

MECHANICAL STOKING.—W. A. Hare (*Pat. J.*, 1,734, 1922). No. 175,342, Oct. 13, 1920. Relates to underfeed stokers.

PEAT.—H. A. Mueller (*Pat. J.*, 1,736, 1922). No. 175,978, Feb. 20, 1922. The percentage of carbon in peat is increased by treatment in closed vessels with bacteria and fungi of the kind used in clarifying sewage. Escaping gases (hydrogen, methane and carbon dioxide) may be utilized for generating power.

METHOD OF FIRING CERAMIC WARES WITH THERMITE.—K. L. Luckhard (*Chem. Zentralb.*, **93**, 689, *Techn., T.*, 1922). Germ. Pat. 347,676. Crucibles or pots filled with thermite are placed round and among the wares, in such a way that they can be refilled, or replaced by other vessels, when the reaction is completed. It is claimed that the temp. can in this way be made to rise gradually.

TESTING FLUE GASES.—H. Atherton (*Pat. J.*, 1,737, 1922). No. 176,396, Aug. 24, 1920. Describes means for obtaining a regular sequence of records of the gases in a number of flues with the aid of a single CO_2 recorder.

BRICK AND POTTERY KILN.—Woodall, Duckham & Co., and A. M. Duckham (*Pat. J.*, 1,737 1922). No. 176,419, Oct. 5, 1920. One or more longitudinal bags are provided, in which combustion is effected, the gases issuing from cheque-work openings in the bags, traversing the stacked goods, and passing through openings in the floor to other kiln chambers or a regenerator and thence to the chimney.

DRYING FURNACE OR KILN.—W. J. Gardner, J. Holland and S. Gardner (*Pat. J.*, 1,737, 1922). No. 176,598, Jan. 26, 1921. Description, with 4 sketches, of a furnace for drying refractory or other goods.

ELECTRIC FURNACE.—A. Imbery (*Pat. J.*, 1,737, 1922). No. 176,658, Feb. 28, 1921. In a resistance and induction furnace, a chamber made of carborundum is serrated or threaded externally to receive a resistance wire or strip made of molybdenum or molybdenum alloy and enclosed in an air-tight chamber containing a protective gas such as hydrogen.

ANNULAR MUFFLE KILN.—Woodall, Duckham & Jones, Ltd., and Sir A. M. Duckham (*Pat. J.*, 1,738, 1922). No. 176,834, Oct. 14, 1920. The kiln is charged and discharged, without interrupting the operation of the conveying platform, through air-tight devices.

PATENT ANNULAR KILN.—Woodall, Duckham & Jones, Ltd., and Sir A. M. Duckham (*Pat. J.*, 1,738, 1922). No. 176,835, Oct. 23, 1920. The materials are carried on a travelling platform and heated by contact with combustion products or burnt by a current of air passing over them. The materials are charged and discharged as described in *Spec.* 176,834 above.

PLANT AND MACHINERY, ETC.

REMOVING LIGHT MATERIALS FROM GRAVEL.—(*Rock Prod.*, **25**, No. 5, 26, 1922). Description of a machine, with sketch.

CLAY-WASHING PLANTS IN BRICK WORKS.—(*Tonind. Ztg.*, **46**, 284, 1922). Some hints on the construction, size, etc., of the plant.

THE DORSTEN BRICK MACHINE.—B. Krieger (*Tonind. Ztg.*, **46**, 373, 1922). An illustrated description of a machine in which the bricks are automatically removed from the press.

A CONVENIENT INSTRUMENT FOR MAKING SHRINKAGE MEASUREMENTS.—W. C. Broga and C. J. Hudson (*J. Amer. Cer. Soc.*, **5**, 34, 1922). Description of an instrument, by means of which clay samples in the form of discs can be quickly and accurately measured both before and after firing and the percentage shrinkage readily determined. The instrument is illustrated.

REMOVING DUST FROM GENERATOR GAS BY ELECTRICITY.—(*Sprech.*, **55**, 145, 1922). An account of the Cottrell-Möller process, which is said to have an efficiency of 99 per cent. and over.

MOULDS FOR MAGNESITE, CHROME AND SILICA BRICKS.—E. E. Ayars (*J. Amer. Cer. Soc.*, **5**, 67, 1922). It is of prime importance, in mould manufacture, to make proper allowance for shrinkage. This amounts to approximately one-quarter inch to the foot, but varies with different classes of raw material. Magnesite and chrome bricks tend to show undue shrinkage along the dimension perpendicular to the one on which they set while under fire. Chrome invariably behaves in this way, but certain classes of magnesite do not exhibit this tendency to any appreciable extent. Experience is the only safe guide. To offset this shrinkage, it is necessary to add an extra allowance (over and above the $\frac{1}{4}$ in.) of approximately $\frac{1}{8}$ in. to 12 in. dimensions, $\frac{3}{8}$ in. to 15 in. and $\frac{1}{4}$ to 18 in. dimensions.

The various kinds of moulds are described, including the open slip and vent bottom type, steel slip liner mould, and the wooden knock-down screw type. The materials used for making them are : soft steel, cold rolled steel, galvanized iron and hard woods. In the *vent bottom* mould, it is important that the sides or webs forming one side of the vent shall extend below the upper surface of the bottom about $\frac{1}{4}$ in., for, if the bottom of the side piece is on a level with the top plane of the mould bottom, more or less of the brick mixture will be forced out through the vent in pounding. The purpose of the vent is then defeated. To further improve the working qualities of the vent, it is desirable to level the wooden bottom back from the vent. This admits more air.

Steel slip-liner moulds. A full steel bottom, made in one piece of $\frac{3}{8}$ in. soft steel is most desirable. A two-piece bottom will not give good results, owing to the vibration incident to moulding. The mould must be fitted with such accuracy that it is absolutely true and tight, good workmanship being most essential. For narrow moulds of this type, a wooden bottom lined with galvanized iron may be used, but only well-seasoned hard wood should be employed, *e.g.*, maple from $1\frac{1}{2}$ to 2 in. thick. To guard against incorrect placing of liners in the mould box by the moulders, a short pin may be put in one side liner and in one end liner, the mould box being notched to correspond. When the liners have become worn owing to slicking off each brick, the "slick" side of the brick will exhibit a depression midway between the ends of the brick. With materials containing a limited amount of moisture, such a brick will crack when turned on to the pallet, since the centre will sag. With other materials the crack may only develop in the fire. A worn liner should be heated in a forge, laid on a flat steel plate, and stretched by means of a "fuller" which is applied paralled to and about $\frac{1}{2}$ inch from the worn edge. Two or three heatings may be required to obtain the proper amount of stretch. A competent mould maker should thus extend the life of a liner to several times the length of the first wear.

For *knock-down or screw moulds*, well-seasoned maple is probably the best wood to use. It should be at least $1\frac{1}{2}$ in. thick.

At the present time a machine for the mechanical moulding of standard 9-in. size is being developed, and in time, it may be adapted to manufacturing larger sizes. Mechanical moulding of standard sizes will probably replace hand moulding within a short time.

QUARRY HAULAGE.—(*Quarry*, **27**, 144, 1922). Description (with photograph) of a locomotive, of low centre of gravity, as used at the granite quarries of the Threlkeld Granite Co. Ltd.

WIRE ROPE DRIVES.—(*Quarry*, **27**, 180, 1922).

GRINDING MEDIA FOR TUBE MILLS.—N. L. Hall (*Rock Prod.*, **25**, No. 8, 29, 1922). The best grinding medium is composed of small parts, which can freely tumble about. The collective weight of the load is more important than that of individual parts of it. Cast-iron balls are cheap, but defective ; forged steel gives a longer term of service.

THE "RAPID" MAGNETIC SEPARATOR.—(*Pot. Gaz.*, **47**, 723, 1922). An improvement on the existing machine takes the form of an intensifier and amplifier. It is said to increase the intensity of the magnetic fall by about

200 to 300%, and the number of magnetic edges is increased by approx. 100%, the consumption of current not being increased. Particles of tungsten ore have been effectively held by the new apparatus.

THE "IDEAL" BUILDING-TILE MACHINE.—(*Cement Eng. News*, **34**, No. 3, 34, 1922). The machine was recently put on the market by the Ideal Concrete Machinery Co. of Cincinnati. It is absolutely automatic in operation, delivers three tiles on a wooden pallet, and is adaptable to the manufacture of various sizes. Concrete is fed into the conveyor at the back, and the operators insert and carry away the pallets.

TRANSPORTING BRICKS.—(*Brick*, **60**, 538, 1922). An illustrated description of a five-ton motor truck having a special cradle attachment for holding a dismountable body with a capacity of 2,500 standard bricks.

ECONOMICAL CRUSHING AND GRINDING.—(*Chem. Age*, **6**, 238, 1922). A brief outline is given of various grinding and crushing machines, including jaw crushers, toothed revolving crushers, the Christy disintegrator, ball and tube mills, edge runners and magnetic separators.

MONORAIL CONVEYORS ON CLAY PLANTS.—Anon. (*Brick*, **60**, 613, 1922). A well-illustrated account of a system which, it is said, can be used to reach almost any point on the plant.

REPAIRING BROKEN GEAR WHEEL TEETH.—G. H. Radebaugh (*Brick*, **60**, 617, 1922).

A WAGGON COUNTER IN BRICK WORKS.—(*Tonind. Ztg.*, **46**, 453, 1922). Description of apparatus for registering the number of waggons passing from the presses to the sheds. An attachment below the rails is actuated by the weight of a passing truck.

ADVANTAGES AND EFFICIENCY OF CHAIN GEARING.—(*Quarry*, **27**, 140, 1922).

PATENTS.

FILTER-PRESSES; BRIQUETTING.—A. G. Bloxam (*Pat. J.*, 1732, 1922). No. 174,657, July 30, 1920. A continuously-operating press for expressing water from, and briquetting materials containing a large proportion of water, *e.g.*, peat or coal slimes.

BRICK-MAKING PLANT.—T. A. Brown and C. Walker (*Pat. J.*, 1732, 1922). No. 174,740, Nov. 2, 1920. A number of parallel drying sheds, having inclined railed floors, are connected by an external track, through turntables.

MOULDING BRICKS.—C. Deregnaucourt (*Pat. J.*, 1732, 1922). No. 174,935, Jan. 31, 1922. Relates to brick presses of the cylinder type.

DISINTEGRATORS.—H. O. Traun's Forschungslaboratorium Ges. (*Pat. J.*, 1736, 1922). No. 176,002, Dec. 24, 1920. A machine for producing dispensoids or colloidal dispensions comprises a wheel carrying beaters and revolving at high speed in a liquid-tight container, so that, at one or more points, the beaters come into close proximity to resisting surfaces. No. 176,003. This machine comprises a cylindrical grinding surface rotating at high speed within a liquid-tight casing and one or more co-operating surfaces formed by the inner periphery of the casing.

BRICK MACHINE.—Whittaker & Co., and N. Whittaker (*Pat. J.*, 1736, 1922). No. 176,044, Oct. 23, 1920. In brick machines of the reciprocating mould-carriage type, the carriage is supported upon rails running on rollers mounted in boxes secured to the machine.

SEPARATORS.—H. H. Verner (*Pat. J.*, 1736, 1922). No. 176,370, Mar. 2, 1922. Substances of different specific gravities are introduced into a liquid of relatively high specific gravity, and are separated by means of two sets of slowly rotating perforated buckets.

III.—FINISHED PRODUCTS: TESTING, ETC.

POROSITY, VI.—DETERMINATION OF POROSITY BY THE METHOD OF GAS EXPANSION.—E. W. Washburn and E. N. Bunting (*J. Amer Cer. Soc.*, **5**, 112, 1922). The principle of the method is an adaptation of that employed by Zehnder (*Ann. Phys.*, **10**, 40, 1903; **15**, 328, 1904) in an effort to perfect a rapid method for determining the true density of a material. The pore volume is measured by allowing the gas which fills the pores to expand into a measured volume and noting the accompaning fall in pressure. The method is in general applicable to pieces of any size and shape and to all classes of porous material. For rapid work with shaped test pieces, a new porosimeter is described, which measures accurately both pore and bulk volume. A complete porosity determination can be made in 5 min. No weighing is required. On ceramic bodies, the results are accurate to one unit in the first decimal place, but considerably higher accuracy can be secured if desired. The results obtained with the new method are in all cases higher, in a number of cases very much higher, than those obtained with the ordinary liquid absorption method. For fired bodies the same results are obtained with dry air, hydrogen or helium as the pore-filling gas. The results show conclusively that complete filling of all the pores in a reasonable time cannot be secured by any of the current methods, using a liquid as the pore-filling agent.

RECENT (GERMAN) PATENT LITERATURE ON SAND-LIME BRICKS.—J. Thamm (*Tonind. Ztg.*, **46**, 271, 419, 1922). A review of the patent literature of the past 10 years dealing with the various stages, from raw materials to the handling of finished products.

RECOMMENDED PROCEDURES FOR DETERMINING POROSITY BY METHODS OF ABSORPTION.—E. W. Washburn and E. N. Bunting (*J. Amer. Cer. Soc.*, **5**, 48, 1922). For shaped test pieces, details of the procedure are given under the headings: Preparation of Test Piece; Determination of Dry Weight; The Absorption Apparatus; Preparation of Standard Vaseline; Saturation Procedure; Calculation; and True Density. A new and accurate pycnometer method, which is applicable to shaped test pieces or granular material, is described. Among other advantages, it gives the operator control over the maximum size opening which he desires to class as part of the pore space. It can also be made to indicate directly the necessary soaking period.

SAND-LIME BRICKS AND SAND-LIME MORTAR.—R. P. Brown (*Rock Prod.*, **25**, No. 6, 36, 1922).

STONE-WARE AS METAL SUBSTITUTE.—Schmidt (*Tonind. Ztg.*, **46**, 434, 1922). The scarcity of copper during the war period in Germany, led to the manufacture of such articles as taps, cooling coils, acetic acid columns, boiling vessels with stirers, etc., out of stoneware. A great advantage is its resistance to acids. This property is tested on the ground body. A weighed quantity (100 gr.) of grains, which pass a 60-mesh and are retained on a 120-mesh sieve, is boiled in a platinum crucible with an acid mixture containing 25 parts conc. H_2SO_4, 10 parts $H\,NO_3$ (sp. gr. 1·4) and 65 parts water, until the water and $H\,NO_3$ have volatilized and the H_2SO_4 commences to fume vigorously. After cooling, the crucible contents are carefully diluted with water and 10 cc. of $H\,NO_3$ are added. The mixture is then boiled again. Upon cooling, the acid is poured off and the grains are thoroughly washed until the washings give no acid reaction. The loss in weight after such treatment varies between 1 to 3 per cent. for good-quality stoneware.

CAUSE OF SPLITTING OF GAS MANTLE SUPPORTS.—M. B. Craven (*Chem. Age.*, **6**, 314, 1922). In comparing samples of English and German gas mantle rings, the chemical analysis revealed no difference which would account for the success of the latter and failure of the former. When heated suddenly, the English samples "split off" or splintered. Two specimens

of English clay rings, one of better quality than the other, and one German ring were examined. The German body had a porosity of 12·6, the inferior English 12·7 and the fairly good English was slightly more dense. The difference was found to be purely physical. The German body broke with quite a beautiful fracture, without striation, the inferior English body exhibited considerable striations, whilst the better English body somewhat resembled the German. In the German body, the grains were very uniform in size, in the inferior English material they were very uneven. The defect, a mechanical one, was therefore, due to lack of proper preparation of the English material. The striations were due entirely to bad pressing. The remedy appeared to be the substitution of kieselguhr for flint, even grinding of the materials, and better pressing.

REFRACTORIES IN THE STEEL PLANT.—W. A. Hull (*Blast Furnace and Steel Plant*, **10**, 100, 1922). A general discussion of the investigations carried out on refractories in America during the past 20 years. Dealing with the necessity for establishing suitable specifications, it is pointed out that the Bureau of Standards is at present working in co-operation with consumers, distributors and producers on the preparation of such specifications for certain materials. Reference is made to the valuable paper by D. W. Ross on *Silica Refractories*, TRANS. **19**, 20 (A), 1920).

DISINTEGRATION OF BLAST FURNACE LININGS.—P. O. Menke (*Blast Furnace and Steel Plant*, **10**, 116, 1922; *Iron Age*, **109**, 528, 1922). The object of the paper is to invite fire-brick makers to undertake experimental tests to find the resistance of the various makes of bricks to zinc fumes. Zinc is charged into the top of the furnace as zinc oxide, finely disseminated through the ore; it descends unchanged to the fusion zone, since the reduction temperature is 1,000°C. and over. It is reduced by solid carbon to metallic zinc; liberated as vapour, it ascends with the gases to the cooler zones. The zinc is re-oxidised between 1,000 and 500°C. ($Zn + CO_2 = ZnO + CO$), but some of the zinc vapour is absorbed by the lining up to as much as 50 per cent. It is usually found as yellow crystals and sometimes in the metallic form. Occasionally, it appears with carbon deposits in the disintegrated portions of the lining. It is also generally assumed that the zinc oxide combines with the alumina in the fire-brick, and since the coefficient of linear expansion of zinc compared with silica is as 60 to 1, it can readily be seen that very great expansive stresses must be exerted in the bricks by impregnation.

DISCUSSION ON THE DISINTEGRATION OF BLAST FURNACE LININGS.—R. M. Howe (*Blast Furnace and Steel Plant*, **10**, 161, 1922). The writer discusses the work published on this subject by the various investigators, beginning with J. Pattinson (1876), in addition to the above contribution by P. O. Menke. The opinions of the earlier writers are summarized as follows: (1) Iron, and possibly its oxides, will cause a precipitation of carbon from carbon monoxide at temperatures between 300° and 400°C. The necessary conditions for such deposition, and subsequent disintegration of the bricks, prevail in blast furnace tops. Since carbon deposition was heavy in several of the linings which failed, many authors believed that this was responsible for the failure. (2) Alkali chlorides are present in many furnaces and they penetrate the lining. They then react with the iron present to form iron chloride, which is volatile. When the temperature is sufficiently high, these chlorides combine with the lining and produce a strong, impervious, porcelain-like protective coating, which shields the inner lining from destructive influences, such as furnace gases, the erosion of the charge, etc. Later publications attribute disintegration to the use of high-barium, high-sulphur ores, and the presence of zinc in the lining was noted by Firmstone in 1903. Commenting on Menke's statement that the quality of furnace linings had deteriorated during the past six years, the writer points out that furnace men usually prefer smooth, uniform bricks, and that they apply tests which favour a dense hard-burned, machine-made brick, but which give results not in conformity with practice. It is the consumer's, not the manufacturer's

problem, to decide whether linings are to be selected by appearance, tests or service.

SCUM ON BRICKS.—H. Hirsch (*Tonind. Ztg.*, **46**, 521, 1922). Discolorations on bricks are usually white or greyish, sometimes brown to blackish, and occasionally green or yellow. They are generally due to the sulphates of calcium, magnesium, sodium and potassium, which can be counteracted in the raw clays by the addition of barium carbonate. The effect of sulphurous fuel is also discussed. The sulphate of manganese may also, in isolated instances, produce discoloration.

"BLUEBELL" SILICA RETORTS.—(*Gas J.*, **158**, 251, 1922) Some interesting facts and comparisons as to the working of "Bluebell" 95% silica retorts, made by Messrs. John G. Stein & Co., of Bonnybridge, were recently published in the *Journal des Usines à Gaz.*" The information was furnished by the Liverpool, Tottenham, and Blackburn Gas undertakings. The three reports agree in stating that the small additional initial outlay is more than set off by the longer life of the retorts and the negligible maintenance expenses. On a setting of six retorts at Liverpool, no repairs were required from January, 1919, to last March, and the present condition suggests a further life of two or three years. The higher conductivity of silica facilitates more rapid and thorough distillation ; the settings at Tottenham worked at 1,350°C.—about 50° above the usual temperature. The engineer at Blackburn maintains that a 25% increased output is attainable with silica retorts. The scale can be removed more easily from silica retorts than from fireclay, and much trouble is thus eliminated. It is essential that the arch of the combustion chamber should be of 95% silica material ; the best practice is to use silica for all parts upwards of the generator nozzles.

EXPERIMENTS ON FLOORS.—(*Brit. Claywr.*, **31**, No. 360, 11, 1922). A discussion of a Report on experiments undertaken by the Building Research Board. Eight types of floor were tested, four of brick and tile, one of wood only, and three of re-inforced concrete. Floor C, made of special-shaped hollow brick blocks 16 in. long and of a total thickness of 6 in. is considered the best for ordinary building purposes.

THE EFFECT OF ELECTRICITY ON CONCRETE AND BRICKWORK.—(*Kalk. Schm.-Ztg.*, **29**, No. 9, 1922). A short review of the literature on the subject is followed by an account of Dr. Reese's work (see TRANS. **20**, 97 (A), 1920).

THE EFFECT OF WEATHER UPON THE STRENGTH OF REFRACTORY BRICKS.—R. M. Howe, S. M. Phelps, and R. F. Ferguson (*J. Amer. Cer. Soc.*, **5**, 107, 1922). Magnesia, silica, and open-textured fireclay bricks should be protected from the action of the weather. The bricks tested were : (1) Fireclay bricks of type "A," made from semi-flint clay, of first-quality refractoriness. (2) Fireclay bricks, type "B," made of about 80% flint clay and bats bonded with 20% plastic clay. (3) Silica bricks, of typical open-hearth and coke-oven quality. (4) Magnesia bricks, machine-made, as used in metallurgy. The chemical analyses were as follows :

	Fireclay A.	Fireclay B.	Silica.	Magnesia.
Silica	50·98	55·02	96·58	7·80
Alumina ..	43·94	39·89	·74	2·42
Ferric Oxide ..	3·16	3·63	·50	3·62
Lime	·36	·86	1·88	3·86
Magnesia ..	·52	·26	·16	82·40
Alkalies	1·32	·79	·21	trace

Cold crushing tests were applied to each set of samples after they had been exposed to the weather, it being assumed that the resistance to abrasion

and impacts, the strength in arches, and the strength under load at high temperatures would vary with the cold crushing strength. Spalling tests were discontinued when it was found that the bricks under investigation were particularly well-bonded. The end cold crushing strengths in pounds per sq. inch are given in the following table :—

	Fireclay A.			Fireclay B.		
	As recd.	After 6 mths.	After 12 mths.	As recd.	After 6 mths.	After 12 mths.
Maximum value ..	1418	1404	1109	1355	909	755
Minimum value ..	782	855	891	545	545	545
Average value ..	1127	1114	1005	885	693	640
Per cent average deviation ..	22·8	13·4	9·3	26·9	20·5	10·1

	Silica.			Magnesia.		
	As recd.	After 6 mths.	After 12 mths.	As recd.	After 6 mths.	After 12 mths.
Maximum value ..	2727	2245	1418	5582	4255	3914
Minimum value ..	1373	1327	909	3273	2726	2062
Average value ..	1830	1680	1111	4464	3780	2978
Per ccnt average deviation ..	23·1	17·7	17·5	14·5	12·7	17·4

In the discussion of the results, it is pointed out that the crushing strength of the magnesia bricks decreased 15% in six months and 33% in 12 months, and this may safely be interpreted as representing still greater decrease in resistance to abrasion, construction stresses and spalling. After weathering for 12 months, these bricks sheared in the load test under pressure at a temperature 40°C. lower than fresh bricks. The decreased strength of the silica bricks was rather unexpected, since they showed no outward signs of deterioration. They, nevertheless. lost 39% of their original strength during the 12 month period. This factor is perhaps even more serious than in the case of the magnesia bricks, for one of the greatest assets of silica bricks is their high strength. The fireclay bricks lost from 1 to 21% in cold crushing strength after 6 months, and from 11 to 28% after 12 months. Additional samples of a very strong brand showed practically no loss in strength after 6 months (over 5,000 pounds), but open porous hand-made bricks were found to bpre actically worthless after storing for 6 months.

REFRACTORY PRODUCTS; THEIR PROPERTIES AND APPLICATION IN FURNACE PRACTICE.—P. G. Strassmann (*Stahl Eis.*, **42**, 24, 1922). A paper read at the general meeting of the "Sudwest" Ironworks, Saarbrücken. The author dealt with the composition, properties, melting-points, sintering points, etc., of refractory clays. Refractory products may be divided into two classes, according to the purpose they are intended to serve : (1) Bricks which have to resist mainly the action of high temperatures

and clear flames; (2) products possessing the property of resistance to slags and chemical reagents. An important consideration is the heat-conductivity of refractory bricks, which depends upon the specific gravity and porosity. The conductivity of a grog brick is always lower than that of a silica brick. The best quality silica bricks are made from the so-called Findlings-quartzite; this material expands considerably during the initial burn, so that the fired brick shows a subsequent expansion of only 1 to 1·5%. Pure Findlings-quartzite melts at cone 35 or above, and bricks made from it are capable of withstanding temperatures of 1,600-1,700°C. for considerable periods, say in a Siemens-Martin furnace. In the discussion, it was pointed out that the foreign ingredients in the refractory raw materials have hitherto not received sufficient attention in judging the qualities of the bricks, and that this would be a useful sphere for future investigations.

THE EFFECT OF POTASH COMPOUNDS ON FIREBRICKS.—(*Tonind. Ztg.*, **46**, 535, 1922). In a boiler fire, the flames from wood fuel pass into a chamber, the lower part of which is paved with firebricks. Owing to strong draught, much dust and ash are carried over from the grates into the chamber. This dust, which is rich in potash, settles on the bricks and forms a sort of glaze. Unfortunately, this glaze-like dust is not permanent; it soon breaks off and the process is repeated. After about a month the chamber has to be re-paved. Bricks of the most varied types, some of them from Europe, have been tried, but without success.

A DEVICE FOR TESTING THE RESISTANCE OF CHINA TO CHIPPING.—Ed. Schramm (*J. Amer. Cer. Soc.*, **5**, 136, 1922). The apparatus (illustrated), of the rigid pendulum type, measures the blow required to chip the edge. Results are reproducible to within about 10%, this variation being due to lack of uniformity in the pieces tested. Vitrified china is more resistant to chipping than either semi-porcelain or European true porcelain.

SCUMMING, EFFLORESCENCE AND "WHITEWASH" ON BRICKS.—Anon. (*Brick*, **60**, 602, 1922). "Whitewash" on bricks may be due to a number of *causes, e.g.,* soluble salts in weathered clay; minerals in unweathered clay which decompose; soluble salts in tempering water; sulphur in lubricating oils, or in kiln gases used for drying; slow drying; sulphur from fuel uniting with lime in clay; action of rain and soluble salts in mortar. The simple barium chloride test is advocated for testing clays. Suggestions for *preventing* whitewash are: use barium compounds to precipitate soluble salts (*e.g.*, 28 lb. barium carbonate per 1,000 bricks); dry ware rapidly; prevent condensation in dryer; use low-sulphur fuel; burn with alternating reducing and oxidising conditions; avoid sulphurous fumes in dryers; careful use of mortar.

THE INFLUENCE OF GRIND AND BURN ON THE CHARACTERISTICS OF SILICA BRICKS.—R. M. Howe and W. R. Kerr (*J. Amer. Cer. Soc.*, **5**, 164, 1922). The samples employed were made by taking mud from the same batch after grinding for 10, 15 and 20 minutes. Samples of each grind were burned at each of 6 temperatures ranging from cone 11 to cone 19. It was found that finer grinding improved the appearance of a brick and increased its strength somewhat, though not in any marked degree, within the commercial limits of grinding. A grinding of from 15 to 20 minutes seemed most desirable. The influence of burn upon several characteristics of silica bricks is shown in the following table:—

Temperature in Cones	AVERAGE VALUE FOR ALL GRINDSAT EACH CONE.			
	Sp. Gravity	Residual Permanent Expansion	Modulus of Rupture	Per Cent Porosity
11	2·50	4·2%	303	27·91
14-15	2·38	2·0%	358	28·30
16-17	2·35	1·3%	444	28·05
17	2·33	·8%	572	28·08
18	2·31	·4%	533	26·72
19	2·30	·2%	614	27·59

This table shows that the firing temperature is the principal factor governing the final strength and also the permanent residual expansion. The maximum temp. of cone 19 yielded the greatest strength and the lowest expansion. The porosity was not affected by the burning temp., but the expansion and strength varied more than 100 per cent over a range of 6 cones.

RESISTANCE TESTS ON FIRE BRICKS UNDER LOADS AT HIGH TEMPERATURES.—E. Sieurin and Fr. Carlsson (*J. Amer. Cer. Soc.*, **5**, 170, 1922). Communicated by the Laboratory of the Höganäs Works, Sweden. In the method employed by the authors, mixtures of fine-ground china clay and ball clay with grog of the same materials were made into 3 cm. cubes and subjected to a pressure of 2 kg. per sq. cm. at temperatures which sufficed to bring about a linear contraction of 0·3 per cent in 2 hours. The heating took place in an electric resistance furnace, the risistor consisting of granular (14—29 mesh) retort carbon contained between two vertical coaxial tubes of carborundum. Carborundum rods were used to support the test pieces and the Seger cones, and to apply the pressures.

Definite quantities of silica, alumina, ferric oxide, lime and magnesia were added, and both the deformation and the usual softening points were determined. The figures obtained are tabulated and plotted.

The authors found that even very small amounts of the oxides of iron, calcium and magnesium brought about a considerable reduction in the resistance to pressure. A minimum in the resistance was observed with silica contents between 60—70 per cent, which does not correspond to the minimum softening point or melting point of clay-silica mixtures. Additions of silica increased the temperature required to deform the specimens, but with high alumina content mechanical failure, due to lack of bonding material, occurred. It is concluded that, for many purposes, clay fire bricks will have to be replaced by more resistant materials, such as bricks made from silica, aluminous mixtures and silicon carbide.

CARBORUNDUM BRICKS.—M. F. Peters (*J. Amer. Cer. Soc.*, **5**, 181, 1922). A study of carborundum—clay mixtures, with reference to the relation between the proportioning and sizing of the constituents and the properties of the refractory as expressed by the tensile strength, the load test, the slagging and the spalling tests. No trouble is experienced in pugging or moulding the mixture if sufficient clay is added to the carborundum to fill the voids and surround each particle with clay. The percentage of clay to be added will depend upon the ratio of the sizes of the carborundum particles. Other things being equal, the tensile strength of any mixture of carborundum and clay is proportional to the bonding power of the clay. When different percentages of carborundum and clay are mixed together, the tensile strength increases rapidly at first, then remains constant, and finally decreases very rapidly. The linear compression varies as the second power of the percentage of carborundum present; bricks that are to be subjected to great pressures must therefore have as high a percentage of carborundum as possible. Carborundum will resist the action of most slags better under reducing than oxidising conditions. It will not resist slags high in iron, lead or lime, but will resist those high in silica. The resistance to spalling depends upon the content of carborundum, the tensile strength, the coefficient of expansion and the thermal conductivity of the clay. A good bond clay should have; (1) high tensile strength; (2) high softening point; (3) low coefficient of expansion; (4) high thermal conductivity, and a good body should have; (1) rigidity at high temperatures; (2) low coefficient of expansion; (3) high thermal conductivity. If the physical destructive forces to be resisted (spalling, compression, abrasion, etc.) are great and the chemical forces small, carborundum will make an excellent grog.

The author also proposes a formula for the estimation of the life of carborundum refractories, and offers an explanation of their physical properties.

THE TESTING OF SILICA BRICKS.—K. H. Endell (*J. Amer. Cer. Soc.*, **5**, 209, 1922). The author submitted some American, English and Swedish

silica bricks to comparative tests, his experiments covering the following properties: (1) Specific gravity; (2) Determination of the temperature of rupture and the softening temp. under a load of 1 kg. per sq. cm. (about 15lb. per sq. in.); (3) Linear expansion after repeated heating up to 1600°C.; (4) Microstructure (proportion of quartz to cristobalite and tridymite). Chemical analysis, temp. of fusion expressed in Seger cones, porosity, and mechanical strength when cold, were not considered of great importance: (1) All specific gravity tests were made on *finely* powdered material in small pycnometers of 3cc. capacity using the boiling procedure; (2) In the underload tests, pressure was applied, in a granular carbon resistance furnace, to small test cylinders by means of a hollow carborundum rod. The temperature was read with an optical pyrometer sighted through this hollow pressure rod. The volume changes were indicated by a pointer and scale and recorded on a rotating drum. The apparatus is illustrated. (3) In view of the fact that steel furnace silica bricks are subjected to a temperature of at least 1600°C, the author deemed it advisable to heat the test pieces in granular carbon resistance furnaces for about 1½ hours up to 1600° and to maintain them at this temp. for half an hour before cooling. Later on, an electric muffle furnace was made use of. (4) In estimating the relative amounts of quartz and cristobalite, the areas occupied by each type of crystal on the photomicrograph were determined with the aid of a transparent cross-section grating.

Suggested specifications for good quality silica bricks are as follows:— True specific gravity not greater than 2·38; not more than 2% permanent linear expansion after treatment as outlined in (3) above; the amount of quartz and silicates as determined under (4) above should not exceed 15%.

In a discussion of the above paper, F. A. Harvey and E. N. McGee make the following observations: (1) *Specific Gravity*. The value more frequently determined by these authors in their work was the apparent sp. gr. The samples were boiled for 1½ hours under a vacuum of at least 20 in. of mercury and the values obtained were about ·02 lower than the true specific gr. as determined by Endell. (2) *Residual Linear Expansion*. In all tests the samples were heated very slowly to 1450°C and maintained at that temp. for 72 hours. The authors doubt whether Dr. Endell's rate of heating to 1600° in 1½ hours is slow enough to give consistent results. (3) *Hot Crushing Strength*. The values as determined on American bricks (Amer. Soc. Testing Materials, method C 16—20) give considerably higher results than those given by Endell for German and American silica bricks.

IV.—MANAGEMENT, ORGANISATION, COSTING, ETC.: COMMERCIAL.

ACCOUNTING TO ELIMINATE WASTE.—G. W. Greenwood (*Brick*, **60**, 368, 1922). A method is outlined by which each department (moulding, setting, burning, handling), sells its product to the next at a price which covers its initial cost, the cost of the direct labour expended in this department, plus the money value of the loss due to breakage, etc.

STORAGE.—F. M. Welch (*Rock Prod.*, **25**, No. 6, 15, 1922). A well illustrated description of the Keystone Gravel Company's plant is given. Six concrete stave bins, holding 2,100 tons of finished product, are supported by a reinforced concrete substructure. A covered belt conveyor carries material from the pit to the screens and crusher; through spouts the graded material passes to the storage bins and is then loaded into trucks.

PRACTICAL SUGGESTIONS FOR MODERNISING A BRICK WORKS.—F. Klages (*Deut. Töp. Zieg. Ztg.*, **53**, 109, 1922). Discusses mainly the question of transporting fresh ware from the press to the drying chambers, whether the latter are on ground level or above the kilns.

THE COST SYSTEM AS AN AID TO EFFICIENT PLANT CONTROL.—D. T. Farnham (*J. Amer. Cer. Soc.*, **5**, 43, 1922). A cost system is described, by means of which complete records are kept of the condition of the plant each day, as compared with an established standard. The following daily records should be available for the General Manager: (1) Output from the machines in tons or thousands compared to standard; (2) Quantity, set and drawn; (3) Quantity shipped; (4) Percentage of firsts, seconds, and lost ware drawn from each kiln, with detailed explanations when firsts fall below an established standard; (5) Drier loss in percentage of output, by products; (6) Number of men at work in each department, and the total tons produced per man per day; (7) Efficiency of operation of each department expressed in terms of a definite percentage of actual accomplishment to realizable standards; (8) Coal and clay on hand compared with minimum standard; (9) Machines shut down, by departments, in terms of percentage of possible running-time. This information should be entered on graphic charts, so as to keep the information before the executive and workmen alike, thus leaving no one in ignorance of the progress of the work as compared with the established standard.

LOADING AND UNLOADING BARGES AUTOMATICALLY.—(*Rock Prod.*, **25**, No. 5, 17, 1922). A description of the construction and operation of the plant of the San Pablo Quarry Co., San Francisco, where barges are loaded in about 2 hours and automatically discharged in four hours.

ADAPTING COAL-WASHING PRINCIPLES TO A SAND AND GRAVEL PLANT.—(*Rock Prod.*, **25**, No. 5, 19, 1922). A well-illustrated account of a plant at Des Moines.

LIME PRODUCTION IN 1921 (U.S.A.).—(*Rock Prod.*, **25**, No. 5, 25, 1922). According to the U.S. Geological Survey, the production was 29 per cent. below that of 1920.

STORAGE SYSTEMS AND MEANS OF RECLAMATION.—C. A. Breskin (*Rock Prod.*, **25**, No. 5, 38, 1922). A well-illustrated account of economic methods of reclaiming materials from storage by means of cranes, single-rope cableways, belt conveyors, power scrapers, etc.

THE ARGENTINE BUILDING-MATERIALS INDUSTRY.—(*Tonind. Ztg.*, **46**, 362, 1922).

THE SELECTION OF MACHINERY.—(*Brit. Claywr.*, **31**, No. 360, 4, 1922).

A MODERN PLANT IN LOS ANGELES.—(*Brit. Claywr.*, **31**, No. 360, 8, 1922). A description (illustrated) of the highly modernised plant of the Los Angeles Pressed Brick Co.

REFRACTORIES.—G. M. Gill (*Brit. Claywr.*, **31**, No. 360, 24, 1922). The importance of proper scientific control over all operations on firebrick works is strongly emphasized in order to effect the production of a higher and more consistent quality of firebrick. Great variations, both in size and quality of firebricks, are typical of most of the firebrick makers of this country. A proper scheme should provide for: (1) The continuous sampling and analyses of mixtures in use, both chemical and physical; (2) The use of heat recorders in kilns; (3) Definite limiting standards for size and shape; (4) Guaranteed working to specifications. Better quality of material is more important to users than price.

INDUSTRIAL ILLUMINATION.—(*Eng. Ind. Man.*, **7**, 450, 1922). The effect of good lighting on production, the choice of lamps and fittings, the correct light distribution, increasing workers' efficiency, and economy in the workshop are discussed at some length.

WORKS ORGANISATION.—T. E. Pattinson (*Eng. Ind. Man.*, **7**, 354, 1922). Deals mainly with the question of idle machines and scrap. Several scrap charts are illustrated.

COSTING IN INDUSTRY.—(*Eng. Ind. Man.*, **7**, 357, 1922). The first portion of a special report of the Costing Conference held in London.

MARKETS FOR CERAMIC WARES IN THE RECONSTRUCTION OF SALONICA.—(*Cer.*, **25**, 132, 1922). A portion of the town, about 1 kilometre square, was destroyed by fire in 1917. There is, consequently, great demand for bricks, tiles, sanitary ware, etc.

THE CERAMIC INDUSTRY OF CZECHO-SLOVAKIA AND ROUMANIA.—(*Cer.*, **25**, 132, 1922). A short outline of the present state of development.

SAND-LIME BRICKS IN THE U.S.A. (1920).—J. Middleton (*Cement Eng. News*, **34**, No. 3, 34, 1922). Statistics.

WHAT SHOULD A FOREMAN KNOW?—(*Claywr.*, **77**, 348, 1922). A discussion on what course of studies should be pursued and what knowledge and information are necessary in order to qualify for foremanship in the clay-working industries.

APPLYING ENGINEERING TO PLANT DESIGN.—F. D. Chase (*Brick*, **60**, 363, 1922). To lay out a plant in a proper and scientific manner, the services of an experienced engineer are indispensable. The problems discussed by the writer in a general way are: (1) location; (2) lay-out; (3) design, and (4) operation.

WORKS TRANSPORT.—R. Fürstenau (*Tonwar. Ofen. Ztg.*, **46**, 28, 1922). By a thorough organisation of the transport arrangements, the production was increased by 100 per cent. on one works within a period of 9 months. The "Schildkröte" lifting waggon is described as particularly suitable.

THE ITALIAN MARKET.—Anon. (*Pot. Glass Rec.*, **4**, 108, 1922).

THE EIGHT-HOUR DAY.—Setter (*Ker. Rund.*, **30**, 171, 1922). Strict observance of the eight-hour working day is impossible under present conditions, and ought not to become statutory.

CONVEYING.—G. F. Zimmer (*Eng. Ind. Man.*, **7**, 334, 1922). The development of mechanical handling devices in Germany during and since the war is discussed, mainly with reference to blast furnaces.

V.—GLASS: GENERAL.

GLASS CONTAINERS.—A. W. Bitting (*J. Amer. Cer. Soc.*, **5**, 85, 1922). A short historical section indicates that glass bottles have been recognised for centuries as superior containers. At present over 4,000 different sizes and shapes are being made and the industry is extending rapidly. 180 lots of beverage bottles were recently tested at the laboratory of the Glass Container Association. Some of the better types, or those approaching the champagne style, were found to withstand an end crushing pressure of 8,000—12,000 lb., a transverse pressure of 800—1,800 lb., a hydrostatic pressure of 400—1,600 lb., and an impact of a 50-lb. hammer falling 2-6 ft. Similar tests are in progress on other types and on the closures employed. Troubles due to alkalinity are rare.

PHYSICAL DEFECTS IN TANK BLOCKS.—G. A. Loomis (*J. Amer. Cer. Soc.*, **5**, 102, 1922). An investigation of some of the leading makes of tank blocks of the so-called flux grade tends to show that these blocks, as a class, are not so free of physical defects, such as fissures and lamination, as could be desired. Photographs are shown of representative sections of the blocks examined. Methods of eliminating these defects are not indicated.

THE ITALIAN GLASS INDUSTRY.—Badermann (*Glas-Ind.*, **33**, 93, 1922). A short account of the more important glass works.

UNBREAKABLE GLASS.—(*Glashütte*, **52**, 149, 1922). A glass expert, Dr. Horak, is reported to have succeeded in making unbreakable glass, suitable for all kinds of cooking vessels, frying pans, etc. The invention has been thoroughly tested.

NOTES ON TEMPERATURES IN GLASS FURNACES II.—Loeser (*Ker. Rund.*, **30**, 48, 1922).

THE IMPORTANCE OF THE RIEKAU PROCESS FOR THE CERAMIC AND GLASS INDUSTRIES.—J. Kieder (*Ker. Rund.*, **30**, 117, 1922). The Riekau process for making steel rules, etc., consists in covering the metal with a substance which is sensitive to light and powdering over with any kind of powder. The latter then adheres to the unlighted portions. The layer of powder is washed off the lighted parts and the remainder can then be melted on before etching. For glass, the procedure would be as follows: The sheet of glass is covered with the sensitive solution, powdered with wax-asphalt and "copied." Oil colour is then applied, and the copy is developed with spirits. The coating thus obtained is then warmed so as to cause the constituents to run together. If necessary, the powdering, etc. can be repeated, and the coating will then stand the most severe etching.

NOTES ON STREAKS, THREADS, ETC., IN GLASS.—(*Sprech.*, **55**, 94, 1922).

OPERATION OF LEHRS.—C. E. Frazier (*J. Amer. Cer. Soc.*, **5**, 37, 1922). Muffle and open types are compared. The latter have the following advantages: (1) more uniform temps. in the annealing chamber; (2) ingress of cold air is prevented, cracking of ware thus being avoided; (3) better control of temp., and greater reliability of pyrometric indications; (4) less fuel per gross of ware is required. The size recommended for average glass is: 8 ft. wide and 65 ft. from centre to centre of sprockets. Chains having a working strain of 5,800 lbs. at 200 ft. per minute are recommended. In the discussion, L. H. Adams points out that the exact annealing schedule for any glass can be computed from the annealing constants of the glass, which are known, or can be determined in the laboratory.

COLUMNAR STRUCTURE IN SANDSTONE WALLS OF A GLASS FURNACE.—J. W. French (*Nature*, **109**, 274, 1922). The lower sandstone course of the side walls of a small tank furnace showed a marked columnar structure on the inner surface after having been in operation for about 7 years. The similarity between the sandstone specimens (illustrated), and those of optical glass (previously noted) is emphasised.

FIRING BOILERS WITH WASTE HEAT FROM GLASS FURNACES.—(*Sprech.*, **55**, 158, 1922). It has been shown both practically and theoretically that from 8 to 12% of the total fuel consumed in the generator can be saved by heating boilers. Six sketches accompany the paper.

METALLIC ETCHINGS ON GLASS AND PORCELAIN.—O. Schwarzbach (*Diamant*, **44**, 338, 1922). For yellow etching, a silver compound, mixed with a colouring agent, is usually applied to glass, and fired on. To obtain a nuance of colours, the object is again heated in a reducing atmosphere, the silver thereby being reduced. This produces a metallic lustre, the colours depending upon the proportion of silver present. A greenish-brown, scintillating gold surface is obtained by applying a mixture of 1 part silver chloride and 5 parts of a raw clay, burning on at a low temp., washing off the clay, and firing a second time under reducing conditions. Different colour effects are produced by varying the proportions, substituting ochre for yellow clay, etc. The nuance of colours and the degree of metallic lustre are dependent upon the amount of silver contained in the mixture and upon the particular silver compound used. Silver nitrate gives a more distinctly yellow colour with less lustre; silver chloride a greenish colour and a gold lustre, whilst silver sulphide produces a yellow etching. The silver content should not exceed the ratio: 1 part silver oxide to 3 parts of neutral body.

RECENT IMPROVEMENTS IN POT FURNACES.—(*Verre*, **2**, 75, 1922). An account of the Stein furnace, manufactured by the Soc. An. des Appareils de Manutention et Fours Stein. This furnace is circular in form and has advantages over other systems in recuperation of heat and economy of fuel consumption. Comparative figures are given for a furnace with 12 covered pots holding 450 kgs.

	Stein kgs.	Hermansen kgs.	Siemens kgs.	Boetius kgs.
Fuel consumption per 24 hours	2450	3550	4000	5400
,, ,, per tonne of glass ..	450	650	750	1000
,, ,, ,, ,, ,, ,, after 3 years working	500	800	1000	1400
Fuel consumption per 24 hours (low burner)	750	900	1200	2500
	hrs.	hrs.	hrs.	hrs.
Time required to melt 5,400 kgs. of glass	14/15	15/16	16/17	17/20

BOROMICA.—(*Verre*, **2**, 83, 1922). Les Cristalleries du Val-St.-Lambert have recently put on the market a new laboratory glass known as Boromica. It is a silica-boric acid glass, with a very low coefficient of expansion, so that it can resist abrupt changes of temperature. It is also highly resistant to fracture; breakage figures obtained by the Fabrique Nationale d'Armes, at Liége, were 17 per cent. as compared with 48% with other types of glass. The glass shows remarkable resistance to the action of chemicals.

ON COLOURING GLASS WITH COPPER.—A. Granger (*Verre*, **2**, 73, 1922). The substitution of the oxides of barium, lead and zinc for lime did not interfere with the development of the blue colour, but the introduction of magnesia was not successful. With increased acidity, the blue developed badly; it was impossible to melt and fine the following glass:—

$$3{\cdot}5\ SiO_2 \left\{ \begin{matrix} 0{\cdot}05\ CuO \\ 0{\cdot}25\ MgO \\ 0{\cdot}70\ Na_2O \end{matrix} \right.$$

Decreasing the alkalies at the expense of CaO produced a tendency towards green, and upon raising the CuO content the glass turned distinctly green, *e.g.*:

$$2{\cdot}5\ SiO_2 \left\{ \begin{matrix} 0{\cdot}10\ CuO \\ 0{\cdot}40\ CaO \\ 0{\cdot}50\ Na_2O \end{matrix} \right. \qquad 2{\cdot}6 SiO_2 \left\{ \begin{matrix} 0{\cdot}11\ CuO \\ 0{\cdot}36\ CaO \\ 0{\cdot}53\ Na_2O \end{matrix} \right.$$

With boric anhydride a rich peacock blue was obtained:—

$$3{\cdot}0\ SiO_2 \left\{ \begin{matrix} 0{\cdot}05\ CuO \\ 0{\cdot}25\ CaO \\ 0{\cdot}70\ Na_2O \end{matrix} \right. \quad 0{\cdot}5\ B_2O_3 \qquad 3{\cdot}0\ SiO_2 \left\{ \begin{matrix} 0{\cdot}10\ CuO \\ 0{\cdot}20\ CaO \\ 0{\cdot}70\ Na_2O \end{matrix} \right. \quad 0{\cdot}5\ B_2O_3$$

The colour is deepened considerably by increasing the B_2O_3 content, whilst a clearer glass is obtained by the simultaneous addition of B_2O_3 and Al_2O_3. Concluding, the author states that it was impossible to produce a satisfactory green with ordinary mixtures like:

$$2{\cdot}5\ SiO_2 \left\{ \begin{matrix} 0{\cdot}11\ CuO \\ 0{\cdot}36\ CuO \\ 0{\cdot}53\ Na_2O, \end{matrix} \right.$$

but that the addition of only 0·027 Fe_2O turned the glass distinctly green. The colour of the glass is closely related to the ratios between the bases and depends upon the alkalinity. Another interesting phenomenon is the tendency of certain glasses, particularly those rich in copper and poor in acids or alcalis, to deposit copper on being chilled. This proves that the production of copper red is not dependent entirely upon the reducing action; the composition of the glaze and the process of cooling also play an important part.

UNBREAKABLE GLASS?—(*Porz. Glas*, **22**, 828, 1922). A new glass invented by Horak and made by the Kavalir Glassworks in Sazau (Bohemia), is said to be practically unbreakable. A tumbler scarcely 1mm. thick with-

stood the heat of a red-hot iron plate and was then immediately immersed in cold water. Two out of three glasses were unaffected by this treatment. Tin was melted in another glass and in still another, cold water was poured over red-hot coke. The glasses do not break if allowed simply to fall to the ground. The glass, which is known as "Silex," contains 98% of quartz. Cooking vessels are also being made from it. It is pointed out, however, that German glass experts have not yet tested the invention.

GLAUBER SALT IN THE GLASS INDUSTRY.—H. Kühl (*Glashütte*, **52**, 225, 1922). A historical introduction is followed by a discussion on the use of sodium sulphate in glass melts.

THE VENETIAN GLASS INDUSTRY.—(*Pot. Gaz.*, **47**, 586, 1922).

MECHANICAL BOTTLE MANUFACTURE.—(*Verre*, **2**, 76, 1922). A new semi-automatic machine (Cuvelier-Boucgniaux patent) is described. The machine has been installed in a glassworks in N. France and is of simple and solid construction. Its output appears to be somewhat higher than that of earlier types. It is capable of turning out perfect screw-top necks and raised bottoms.

THE HANDLING, STORING AND SETTING OF GLASS POTS.—W. M. Clark & J. H. Forsyth (*J. Amer. Cer. Coc.*, **5**, 146, 1922). Precautions indicated include: careful packing for shipment in rain-proof box cars, well-padded pot carriages equipped with spring suspensions; storage in a warm, dry room; careful preparation of the furnace bench to ensure an even distribution of load on the bottom of the pot and to make certain that the pot is level or tilted slightly forward. Unnecessary jolts often result in damage which only becomes apparent when the pot is heated up.

A SMALL GLASS TANK.—H. T. Bellamy (*J. Amer. Cer. Soc.*, **5**, 157, 1922). The furnace is fed from three burners and uses about 24,000 ft. of 300 B.T.U. gas per 24 hours. It successfully melts high lead crystal, alabaster, opal, gold ruby and green opalescent glasses. A figure is given showing the construction.

THE MANUFACTURE OF GLASS IN ELECTRIC RADIATION FURNACES.—V. M. Sauvegeon (*Chim. Ind.*, **7**, 452, 1922). The writer describes his personal experiences which commenced in 1908. Three sketches are given of the furnace which measures 1·22 in. long, 1·37 in. wide and 1·16 in. in height. The pot is capable of holding 400 kg. of glass.

THE BAVARIAN PLATE-GLASS INDUSTRY.—(*Diamant*, **44**, 289,1922).

Patents.

GLASS MANUFACTURE.—W. J. Miller (*Pat. J.*, 1732, 1922). No. 174,644, Sept., 24. 1920. Relates to pressing mechansm. An air cushion is devised for cushioning the movement of the blunger in a press-and-blow machine.

TRANSFERRING PARISONS.—W. J. Miller (*Pat. J.*, 1732, 1922). No. 174645, Sept. 24, 1920. A device for transferring the parisons to the finishing moulds in a double-table automatic machine.

LAMP BULB MACHINE.—Br. Thomson-Houston Co. (*Pat. J.*, 1734, 1922). No. 175440, Nov. 24, 1920. An improved machine for making small electric lamp bulbs from glass tubing is described.

DELIVERING MOLTEN GLASS.—Owens Bottle Co. (*Pat. J.*, 1735, 1922). No. 175949. May 30, 1921. An apparatus of the reciprocating plunger type for delivering molten glass from an orifice. Means are provided for manually adjusting the movements of the plunger during operations, for shearing the extended metal, and for timing and adjusting the shearing mechanism.

BOTTLE-BLOWING MACHINE.—W. J. Mellersh-Jackson (*Pat. J.*, 1736, 1922). No. 176017, Aug. 24, 1920. Relates to a semi-automatic pneumatically-operated machine.

MAKING HOLLOW GLASS CYLINDERS.—H. P. Amphlett and Hume Pipe and Concrete Constr. Co. (*Pat. J.*, 1736, 1922). No. 176058, Oct. 30, 1920. Vitreous material, heated to a fluid state, is shaped while being subjected in a mould to centrifugal force sufficient to effect expulsion from, or rearrangement within the material, of matter of different sp. grs. the material at the same time being freed of air bubbles.

TITANIC OXIDE IN GLASS.—H. Wade (*Pat. J.*, 1737, 1922). No. 176430. Oct. 29, 1920. Titanic oxide is introduced in the ratio of not less than 25% of the whole batch. Example: silica 69 parts by weight, borax 10, sodium carbonate 29, lime 7, titanic oxide 45.

MOULDING GLASS BY CENTRIFUGAL FORCE.—H. P. Amphlett and Hume Pipe and Concrete Constr. Co. Ltd. (*Pat. J.*, 1737, 1922). No. 176737, Oct. 30, 1920. Describes how hollow or perforated blanks of vitreous material are brought to final form in centrifugal containing moulds (Spec., 176058).

DELIVERING MOLTEN GLASS.—T. C. Moorshead (*Pat. J.*, 1738, 1922). No. 179980. Jan. 26, 1921. Describes means whereby the molten glass leaving the furnace is maintained at furnace temp. until it reaches the mould.

GRINDING, POLISHING AND BURNISHING GLASS.—J. Carrie (*Pat. J.*, 1738, 1922). No. 177049. Mar. 12, 1921.

GLASS FURNACE.—M. W. Travers (*Pat. J.*, 1738, 1922). No. 177085, May 3, 1921. Gas from producers is supplied with secondary air under pressure from inlets, so that its combustion is effected as it rises through the eye of the furnace.

GLASS GATHERING APPARATUS.—Pilkington Bros. Ltd., A. C. Pilkington and J. Gaskell (*Pat. J.*, 1740, 1922). No. 177682, Mar. 3, 1921. Relates to apparatus of the pipette type. The lower opening is so adapted that, on discharging the metal, any chilled strings are removed from the opening. The device is particularly intended for gathering and delivering metal for casting search-light mirrors.

VI.—CEMENT, CONCRETE, MORTARS, ETC.

CEMENT GOODS.—F. Stroux (*Tonind. Ztg.*, **46**, 391, 1922). Discusses the past and future of the cement goods and artificial stone industry.

LIMESTONE CONCRETE FOR CEILINGS, ETC.—(*Kalk. Schm.-Ztg.*, **29**, No. 6, 1922). At the instigation of the Berlin police authorities, tests were carried out by the Bureau for Testing Materials with a view to determining whether the material was satisfactory as regards carrying capacity and resistance to fire. The data is tabulated.

THE MANUFACTURE AND USES OF LIME PRODUCTS.—N. V. S. Knibbs (*Chem. Age.*, **6**, 105, 1922).

THE INDIANA PORTLAND CEMENT COMPANY'S PLANT.—(*Rock Prod.*, **25**, No. 7, 19, 1922). A well-illustrated description.

MAKING CONCRETE PRODUCTS.—J. W. Lowell (*Rock Prod.*, **25**, No. 7, 34, 1922). Seven plans are given, illustrating the layout of a plant. Marketing, in addition to technical production problems, is also dealt with.

AN ACID-PROOF CEMENT.—(*Kalk. Schm.-Ztg.*, **29**, No. 7, 1922). A short account of a product recently put on the market under the name of "Certus Cement." The composition is not indicated.

CHEMICAL ASPECTS OF CEMENT.—C. H. Desch (*Chem. Age*, **6**, 346, 424, 1922). Le Chatelier's theory of setting has been proved to be substantially correct. The temp. at which the lime is heated has a very great

effect on the cement. Free lime is an objectionable constituent, but it cannot be avoided altogether. Magnesia alone will not cause expansion, but in the presence of calcium sulphate it is apt to be harmful. Cement should be as dense and non-porous as possible. Bad proportioning of the aggregate is the cause of many defects. The addition of materials of a puzzolana character renders the cement more resistant to sea water. Another method is to replace alumina by ferric oxide, as is done successfully in Germany. In the setting process, the question of the behaviour of catalysts is still rather obscure. Trass containing a proportion of active silica is also a useful constituent. With regard to the use of blast furnace slag, the author does not agree with the widespread opinion that calcium sulphide is a harmful ingredient. The presence of ferrous sulphide might lead to disastrous results. Finely granulated slag mixed with Portland cement gives increased strength and greater resistance to sea water; this is the German iron-Portland Cement (30% slag and 70% clinker). The question of a standard specification for cements made from blast furnace slags is now under consideration.

PRESENT AND FUTURE TECHNICAL PROBLEMS IN CONCRETE AND FERRO-CONCRETE CONSTRUCTION.—W. Petry (*Tonind. Ztg.*, **46**, 223, 1922). The proposed revision of the concrete and ferro-concrete specifications and re-casting of the cement standards are discussed, from the point of view of modern requirements. The article closes with a brief note on the training of personnel.

STEEL-CONCRETE.—A. Kleinlogel (*Tonind. Ztg.*, **46**, 228, 1922). A short account of the properties and uses.

THE CEMENT-GOODS MACHINERY INDUSTRY OF SAXONY.—(*Tonind. Ztg.*, **46**, 260, 1922).

CEMENT AND PETROGRAPHIC OPTICS.—M. Pulfrich (*Tonind. Ztg.*, **46**, 378, 1922). The optical constants of a body constitute one of its fundamental properties, like its specific gravity. The paper gives a brief description of two improved petrographic investigation methods. The one permits observation of interference figures of very small crystals in powders or thin section. By means of the other, the optical immersion method, it is possible to determine refractive indices, with sufficient accuracy to the third place of decimals of material with a grain-size down to one-hundredth of a mm. The microscope (illustrated), is fitted with double mirrors, which illuminate the whole field of the microscope with plain polarised light. The advantages of this arrangement are: (1) the field is not restricted by the polariser in applying lower magnifications; (2) with immersion objectives the whole of the numerical aperture of the microscope condenser can be utilised; (3) the method is less expensive, since the mirrors can be easily prepared and one nicol is dispensed with. For the examination of cements (immersion method) the author used a measuring scale consisting of five liquids with the following refractive indices: glycerine 1·455; toluene 1·491; phenetol 1·511; quinoline 1·619 and methylene iodide 1·742. Two microphotographs of cement are included.

THE TECHNICAL IMPORTANCE OF THE CEMENT-MAKING CHINESE WHITE ANTS.—(*Tonind. Ztg.*, **46**, 387, 1922). At a meeting of the Rockefeller Institute, New York, American scientists, lately returned from Peking, reported the discovery by two Chinese investigators of a colony of insects in the Yang-tsi-Kiang valley. These insects build up their habitations of a material which in composition is identical with, and in mechanical properties, probably superior to Portland cement. The possibility of rearing these insects on the soy bean, which grows in such abundance in China, opens up wide economic possibilities.

NEW DEVELOPMENTS IN CONCRETE MIXING.—"Omega" (*Eng. Ind. Man.*, **7**, 441, 1922). An account of two new devices, one of which proportions the concrete by weight instead of measurement, and the other produces concrete continuously instead of intermittently. The first has

been developed by the Lakewood Engineering Co., of Cleveland, Ohio. The second is known as the "Aero" Mixer, and has been in use for some years, chiefly in Switzerland and France. The wetted and individually separated aggregate particles are passed through a cloud of cement blown in the opposite end of a slowly rotating cylinder.

MAKING PREPARED GYPSUM PLASTER.—(*Rock Prod.*, **25,** No. 9, 30, 1922). The compact and efficient plant of the King's Crown Plaster Co. is described. There are numerous illustrations.

GRADING AND MEASURING CONCRETE AGGREGATES.—R. C. Yeoman (*Rock Prod.*, **25,** No. 9, 40, 1922). The lack of tolerance in specifications is more harmful than beneficial. This question is discussed more particularly with reference to American conditions.

DISTINGUISHING PLASTER OF PARIS FROM KEENE'S CEMENT.—A. Moye (*Tonind. Ztg.*, **46,** 572, 1922). In powdered form, one litre of plaster of Paris weighs from 650—850 grs., Keene's cement from 900—1,200 gr. But the safest method is to mix with water and note the time of setting.

SPECIAL CEMENTS FROM DOLOMITE AND KAOLIN.—(*Claywr.*, **77,** 348, 1922). Free lime in dolomite calcined above 800° causes excessive shrinkage and cracking. Cement with practically no free lime may be made by calcining the dolomite to a low temperature (600), thus decomposing the magnesium carbonate, but not the calcium carbonate. But suitable agents may be added to counteract free lime in dolomite calcined at high temp. (1,000°). By using kaolin calcined at 750 and dolomite calcined at 1,000, the lime and calcined kaolin reacted to form a puzzuolana cement.

MARBLE COATINGS ON CONCRETE AND BRICKWORK; CAUSE OF DULLNESS AND "SCUMMING."—H. Nitzsche (*Tonind. Ztg.*, **46,** 553, 1922). Various kinds of marble (Italian, Belgian, Hungarian, etc.) were used to cover the walls and columns of a synagogue built about 10 years ago. The polish has now to a large extent disappeared, and the marble is covered in many places with a white scum. Investigation showed that the trouble was due to moisture in the brickwork and the presence of soluble sulphates in the mortar used to hold the marble slabs. This mortar contained gypsum. A micro-photograph is shown.

TWENTY-YEAR TESTS ON CEMENT AND MORTAR MATERIALS.—(*Cement Eng. News*, **34,** No. 4, 28, 1922). Taken from *J. College Eng.*, (*Tokio*), **10,** 155, 1920. Neat cement briquets attained maximum strength in sea water in less than a year, after which they rapidly declined. In some cases they lost their tensile strength completely, in 4 or 5 years. This peculiarity is ascribed to excessive crystallisation. Compressive strength is, however, retained, or even increased. Cement-sand mortar mixtures (1 : 2) showed progressive increase of strength in air and sea water. Curves show an eventually attainable tensile strength of 1,210 and 710 lb. per sq. in. respectively. No material improvement was noted as the result of curving mortars in fresh water. A series of tests was carried out on the use of volcanic ashes (Japanese), in cements. In air, the greater the amount of ashes used, the lower the strength of the briquets. Straight cement mortars were in every case stronger in air, but in sea water the ash-cement mortars were decidedly superior, though weaker under compression. Analyses of ash-cement mortar blocks kept in sea water show that a portion of insoluble silica enters into combination to form soluble compounds in the course of time, as is indicated by the following figures :—

Time.	Silica Soluble.	(Total 100) Insoluble.
Before induration	43·73	56·27
2 months	46·28	53·72
7 ,, ...	47·29	52·71
14 ,, ...	50·08	49·92
38 ,, ...	53·95	46·05

CEMENT MAKING IN IOWA.—(*Rock Prod.*, **25,** No. 9, 21, 1922).

A MODERN JAPANESE CEMENT PLANT.—(*Rock Prod.*, **25,** No. 8, 38, 1922). An account, with numerous photographic illustrations and sketches, of the Asano Cement Company's latest plant at Kawa-saki.

THE CONTINENTAL PORTLAND CEMENT COMPANY.—(*Cement Eng. News*, **34,** No. 3, 18, 1922). The plant is situated near St. Louis and was built in 1908. A short account is given of its arrangement and of the steps taken to increase the capacity.

THE DEFLECTION OF REINFORCED CONCRETE BEAMS OF RECTANGULAR CROSS-SECTION.—F. P. McKibben (*Cement Eng. News*, **34,** No. 3, 20, 1922). Numerous formulae are given to illustrate the method of computing the vertical deflection at the centre of a beam of given dimensions due to a given load.

MODERN PLANT FOR MANUFACTURING FINISHED LIME.—(*Cement Eng. News*, **34,** No. 3, 30, 1922). An illustrated description of the Luckey Lime and Supply Co.'s plant, at Luckey, Ohio.

CONCRETE STOCK-WATERING TANKS.—(*Cement Eng, News*, **34,** No. 4, 21, 1922). Gives practical details of the construction of concrete water tanks for farms.

NEW LABORATORY ABRASION TEST FOR CONCRETE.—C. H. Scholer (*Cement Eng. News*, **34,** No. 4, 23, 1922). The test was developed at the Engineering Experiment Station of the Kansas State Agricultural College. 9-in. spheres are cast, and after proper ageing, are submitted to abrasion in a standard brick rattler using a standard abrasive charge. Definite results are obtained with 900 revolutions. The data are tabulated.

THE MANUFACTURE OF FUSED CEMENT.—E. Candlot (*Chim. Ind.*, **7,** 456, 1922). In 1908, Bied demonstrated the possibility of obtaining cement by the fusion of bauxite and lime. With bauxite containing 7% SiO_2, 60% Al_2O_3 and 15% Fe_2O_3, the following fusion-points are obtained:

100 bauxite 60 limestone 1,450 ; 100 bauxite 100 limestone 1385
100 ,, 80 ,, 1,430 ; 100 ,, 120 ,, 1,400

The furnaces employed are of the water-jacket and the electric types. Fused cement sets slowly and hardens rapidly. A road laid on the Saturday evening was capable of supporting the passage of a 5-ton tractor the following Monday.

FERRO-CONCRETE RIVER CRAFT AND FLOATING DOCKS.—(*Tonind. Ztg.*, **46,** 508, 1922). In the Minden Ferro-concrete Shipbuilding Yards, the double wooden framework has been abandoned in favour of a concrete dock, which serves as a permanent shell for ship construction. The latest concrete vessels draw only a few inches of water more than iron ships of the same capacity, and the cost of construction is one-third cheaper.

CEMENT MAKING IN IOWA.—(*Rock Prod.*, **25,** No. 8, 23, 1922). A well-illustrated account of the cement plants in Iowa.

VII.—CHEMICAL AND ANALYTICAL PROCESSES.

DETERMINATION OF THE SURFACE AREA OF GLASS POWDER.—H. Wolff (*Zeits. angew. Chem.*, **35,** 138, 1922). The surface area in sq. cm. of glass powder can be determined by measuring the loss in weight over a specified period of (1) a sheet of glass of known area, and (2) powder of given grain size, after vigorously stirring in a hot soda solution.

REPORT OF THE COMMISSION ON LABORATORY APPARATUS.—(*Zeits. angew. Chem.*, **35,** 142, 1922). This report deals with the standardization of glass beakers, dishes, and watch glasses.

THE BAUR-CRAMER APPARATUS FOR THE DETERMINATION OF CO_2.—H. Hecht. (*Tonind. Ztg.*, **46**, 310, 1922)

REPORT OF THE COMMISSION ON LABORATORY APPARATUS.—(*Zeits. angew. Chem.*, **35**, 145, 1922). Deals with the standardization of beakers.

THE FURNISHING AND EQUIPMENT OF LABORATORIES.—(*Chem. Age*, **6**, 338, 1922). Some notes by a Committee of the Chemical Society.

THE PREPARATION OF CALCIUM CHLORIDE WITH SIMULTANEOUS PRODUCTION OF A LIME FERTILIZER.—H. Molitor (*Glashütte*, **52**, 97, 1922). An account of Solway and Mond's work.

ADSORPTION: ITS SIGNIFICANCE IN CATALYTIC PROCESSES.—A. Pickles (*Chem. Age*, **6**, 586, 1922). A short survey of the subject, indicating the difference between the absorption and adsorption processes.

ELECTRO-OSMOSIS.—P. Bary (*Chem. Ind.*, **7**, 640, 1922). A general review of the subject. There are 58 references.

NEW METHOD FOR THE PREPARATION OF PURE CERIA EARTH COMPOUNDS.—R. H. F. Manske (*Can. Chem. Metall.*, **6**, 83, 1922). The method assumes the presence of about 50% of cerium in a mixture of the sulphates of cerium, lanthanum, neodymium and praeseodymium. A cold saturated solution (zero) is heated to 41°C. until a mother liquor is obtained that does not show the absorption spectrum of neodymium in thick concentrated layers. The cerium is separated from this and the pure praeseodymium precipitated by oxalic acid. Fractionation is continued by this process, ten fractions serving to give a very pure product. The last fraction is then dissolved in ice water to saturation and rapidly heated to 65°C. and then vigorously stirred. Fractionation is continued until the arc spectrum of lanthanum ceases to show in the mother liquor, which then contains pure neodymium with some cerium.

VIII.—HISTORICAL, EDUCATIONAL INSTITUTIONS, ETC.

WHAT RESEARCH MEANS TO THE CLAY INDUSTRY.—M. B. Greenough (*Brick*, **60**, 458, 1922). The article gives some interesting details of the research work which is now being conducted by the American National Associations. Instalments paid into a joint research fund since July, together with additional revenue from interest, aggregated 5,633 dollars on Jan. 1st. During the same six months the disbursements amounted to 2,857 dollars. The distinguishing feature of this research programme is the co-operation of the Federal Government through the Bureau of Mines and the Bureau of Standards, coupled with other agencies like the University of Illinois, made available through the American Ceramic Society.

THE USE OF CERAMICS IN ARCHITECTURE.—A. B. Pite (*Pot. Gaz.*, **47**, 736, 1922). Report of a lecture before the Art Section of the Ceramic Society.

MODERN RUSSIAN POTTERY.—(*Pot. Gaz.*, **47**, 748, 1922). A short account (by S. V. Tchechonin) of the work produced by the National Porcelain Factory, one of the few concerns which did not fall into a ruinous condition during the revolutionary period.

THE LABORATORY OF THE FRENCH CERAMIC MANUFACTURERS' SYNDICATE.—L. Yeatman (*Cer.*, **25**, 129, 1922). The French industry has long suffered from the lack of a central organisation capable of carrying out chemical and scientific research work. An account is given of the work done at the Pottery Laboratory at Stoke-on-Trent, and a proposal is put forward that the above institution should be reconstituted on similar lines.

THE ORIGIN OF BRICKS.—(*Claywr.*, **77**, 347, 1922). Historical.

PERSIAN POTTERY.—(*Ker. Rund.*, **30**, 183, 1922. *Tonind. Ztg.*, **46**, 541, 1922). An account of the collections at the Kaiser Friedrich Museum, Berlin.

NOTES ON THE DUTCH BRICK INDUSTRY.—P. Thor (*Tonind. Ztg.*, **46**, 551, 1922).

PERMANENT COLOUR SCHEMES IN BUILDING.—H. Ricardo (*Brit. Claywr.*, **31**, No. 361, 60, 1922).

SAND-LIME BRICKWORKS IN EGYPT.—(*Tonind. Ztg.*, **46**, 427, 1922).
A MODERN BRICK PLANT IN LOS ANGELES.—(*Brit. Claywr.*, **31**, No. 360, 8, 1922).

THE DEVELOPMENT OF CERAMIC WORK AT THE UNIVERSITY OF NORTH DAKOTA.—M. K. Cable (*J. Amer. Cer. Soc.*, **5**, 140, 1922). The correlation of research in chemical and experimental laboratories and the cultural value of the work are discussed. The inexhaustible supplies of material in the State are being utilized. Six photographic reproductions illustrate the paper.

THE BAVARIAN POTTERY INDUSTRY.—G. R. v. Ebert (*Sprech.*, **55**, 194, 1922). Mainly historical.

A DECORATED PLAQUE BY ORAZIO FONTANA.—B. Rackham. (*Faenza*, **10**, 3, 1922). A description of a scenic plaque in the Salting Collection in the Victoria and Albert Museum, London. The plaque bears the date 1541, and upon it is depicted a view of the city of Urbino (illustrated).

THE VISCHE PORCELAIN FACTORY (1765–1768).—A. Tallone (*Faenza*, **10**, 5, 1922).

NEW WRIGLEY BUILDING, CHICAGO.—(*Claywr.*, **77**, 437, 1922). Illustrated description of large and monumental building in terra cotta.

Abstracts.

I.—RAW MATERIALS:

GENERAL.

THE CLAY AND KAOLIN WORKS OF SAXONY.—(*Tonind. Ztg.*, **46**, 599, 1922). Statistics for the year 1920.

THE ORIGIN OF FLUORSPAR DEPOSITS.—(*Quarry*, **27**, 219, 1922). Adapted from Summary Report, 1920, Part D, Geological Survey of Canada, Ottawa, 1921.

SILICA.—(*Claywr*, **77**, 565, 1922). A short account of the many uses to which silica is put.

GRAPHITE IN 1920 AND 1921.—(*J. Soc. Chem. Ind.*, **41**, 246R, 1922). Statistics.

A NEW DEPOSIT OF MAGNESITE.—Le Guen (*Rev. Mat. Constr. Trav. Pub.*, No. 152, 74B, 1922). The deposit has been discovered since the war at Val d'Elsa, Tuscany, Italy, and consists of a very pure, white magnesium carbonate. The quantity estimated exceeds 120,000 tonnes. Its composition is generally constant: Silica 1·55–0·90%; oxides of iron and alumina 1·60–1·0%; lime 0·95–0·2%; magnesium carbonate 95·85–97·80%. Italy will, therefore, soon pass from the position of importer to that of exporter of pure magnesite.

RAW MATERIALS: OCCURRENCE, PREPARATION, ETC.

KAOLIN DEPOSIT NEAR NECKARSTEINACH.—A. Cobenzl (*Ker. Rund.*, **30**, 202, 1922). The deposit is said to contain kaolin of excellent quality. Average results of analyses gave 8–10% water, 52–60% silica, 25-30% alumina, 0·8–2·0% iron oxide, 0·3–0·6% lime, 0·8–1·3% magnesia, and 1·2–4·9% alkalies. Washings of the material at various depths gave the following results:—

Material	Moisture %	Coarse Sand (over 250-mesh) %	Fine Sand (thro. 250-mesh) %	Washed Kaolin %	Ratio Kaolin to Sand
At depth of about 2 m.	14·9	49	18	16	20 : 80
,, ,, ,, 3 m.	13·0	2·3	52	32	37 : 63
,, ,, ,, 4 m.	15·3	3·0	41	39	47 : 53

PURE CALCIUM CARBONATE, OR "ICELAND SPAR."—O. Bowles (*Rock Prod.*, **25**, No. 11, 25, 1922). An account of the occurrences, properties and uses of limestone in its most valuable form.

AUSTRALIAN POTTERY CLAY.—(*Bull. Imp. Inst.*, **19**, 765, 1921), White clay from a deposit near Bendigo, Victoria, was recently examined to ascertain its suitability for making porcelain and refractory bricks. After washing to remove about 4% of gritty matter (quartz and felspar), analysis gave the following: 65·25 SiO_2, 22·16% Al_2O_3, 0·87% Fe_2O_3, 0·59% TiO, 0·38% CaO, 0·82% MgO, 0·42% Na_2O, 1·68% K_2O, 0·30 SO_3, 7·58% loss on ignition. On mixing the dry washed clay with water, a very plastic mass was obtained, which worked well. A strong white biscuit was yielded after firing for 6 hours to 1,050°C. Total shrinkage about 8%., water absorption 13·5%, and transverse breaking stress about 870 lb. per sq. in. Porcelain

produced by adding varying quantities of Cornish stone and ground flint was in all cases too fusible and not of good white colour. A strong impermeable dull-white stoneware was obtained by mixing with a proportion of Cornish stone and firing to 1,200°C. The clay would probably be suitable also for the production of felspathic faience. The unwashed material is unsuitable for the manufacture of refractory bricks. It is concluded that, after washing, the clay is suitable for making white permeable pottery, which can be glazed to yield a fine white earthenware. It is not suitable for hard porcelain, but with suitable felspathic and siliceous materials, it could probably be used for producing semi-porcelain or impermeable stoneware. When mixed with about 50% of grog, the washed clay would also serve for the production of second-grade refractory bricks.

REPORT ON THE CLAY USED FOR SOMA WARES.—S. Nôtomi (*Jap. Geological Survey, Bull.*, No. 67). The Geology of the region surrounding the village of Obori, where the Soma stone-wares are manufactured, is described. The clayey stratum of the region has probably been formed by the deposition of weathered gneiss and granitic sandstone and is composed of granitic sand and kaolin. It contains also a considerable proportion of peat.
S. KONDO.

MAGNESITE PRODUCTION IN 1921 (U.S.A.).—(*Rock Prod.*, **25,** No. 12, 54, 1921). The consumption of magnesite in 1921 in the U.S.A. was about 113,500 short tons, 58% of which was imported.

THE PACIFIC COAST MAGNESITES.—W. P. Bartlett (*Rock Prod.*, **25,** No. 12, 55, 1922).

THE NEW JERSEY POTASH MARLS.—J. H. Ruckman (*Rock Prod.*, **25**, No. 13, 21, 1922).

CALIFORNIA GYPSUM.—F. J. Grinswold (*Rock Prod.*, **25,** No. 13, 34, 1922). The deposits are uniformly of very pure quality, containing from 91 to 99 per cent. pure gypsum.

MAGNESITE DEPOSIT IN NEVADA, U.S.A.—(*Rock Prod.*, **25,** No. 15, 13, 1922). A large deposit, understood for a long time to be kaolin, but now recognised to be magnesite, is found in Clark County, Neveda. It is of sedimentary origin and not a vein deposit. It promises to yield a large and readily available supply.

DERRY FELSPAR QUARRY.—N. B. Davis (*J. Amer. Cer. Soc.*, **5,** 294, 1922). A description is given of a large deposit of high-grade potash felspar known as Derry Quarry at Buckingham, Quebec. The method of operating the quarry is described, with 4 illustrations. Typical analyses of the material show 65·09–65·8% SiO_2, 18·85–19·74 Al_2O_3 and 13·42–12·32 potash.

CERAMIC MATERIALS IN THE SAGA PREFECTURE.—K. Ihara (*J. Jap. Cer. Ass.*, 353, 3, 1922). A detailed geological survey of the districts producing raw materials for pottery is given. Izumiyama which was found about three hundred years ago by S Li and has since been used as the chief raw material of the famous Arita porcelain is a decomposed liparite. The liparite is composed of fine-grained felspar and quartz, the former being kaolinized markedly; it has sometimes minute iron pyrites and is silicified in part by fine veins of chalcedony. The presence of alum in some of the cleavages and the strong smell of sulphur in the mine indicate that the decomposition of its felspar has been caused by the action of sulphurous gas and hot spring water. It is classified in four kinds; the best one has a composition of 3·12% loss on ignition, 76·07% silica, 14·11% alumina, 0·88% ferric oxide, 1·97% lime, traces of manganous oxide and magnesia, 0·15% titanium dioxide, 2·67% potash and 1·36% soda. Some other liparites have probably been decomposed by weathering. S. KONDO.

CLAYS OF MOUNT HONGO IN THE FUKUSHIMA PREFECTURE.—K. Hojo (*J. Jap. Cer. Ass.*, 355, 98, 1922). Hongo is one of the chief porcelain producing districts in Japan. the products being known as Aizu ware.

The Mt. Hongo clays are the chief body materials of the Aizu porcelain ; they are decomposed liparite. Clays of the best quality have the following composition :

Name of clay.	Ig. loss	SiO_2	Al_2O_3	Fe_2O_3	MnO	CaO	MgO	P_2O_5	Na_2O	K_2O
Jari ..	4·34	78·50	13·16	0·46	0·52	1·29	0·26	—	0·97	0·81
Okubo ..	5·14	71·43	17·83	0·55	—	1·87	0·79	0·46	1·27	0·90

S. KONDO

PATENTS.

CONCENTRATING SUSPENSIONS OF CLAY.—Osmosis Co., Ltd., J.S. Highfield and D. Laurie (*Pat. J.*, 1737, 1922). No. 176,549, Dec. 21, 1920. A clay suspension obtained with an electrolyte is allowed to settle in a tank while the lower parts of the material is maintained in a state of slow motion sufficient to prevent the formation of a solid deposit. The super-natant liquid is then drawn off, leaving a lower layer of creamy consistancy. Figures are shown of suitable apparatus.

MAGNESIUM CARBONATE FROM DOLOMITE.—T. Simon (*Pat. J.*, 1737, 1922). No. 176,785, Mar. 7, 1922. Magnesium carbonate is prepared from dolomite by treating a suspension of burnt dolomite in water or alkaline carbonate soln. with CO_2 under ordinary, diminished, or increased pressure, the proportion of the burnt dolomite being so adjusted that the magnesia in the dolomite "is always present as a deposit." *E.g.*, 100 kg. burnt dolomite are mixed with 1,500 litres of water and treated with CO_2 under pressure. The mixture is filtered, and about 70 kg. hydrated magnesium carbonate are obtained from the filtrate by heating.

THORIUM OXIDE AND SALTS.—H. Wade (*Pat. J.*, 1745, 1922). No. 179,309, Feb. 3, 1921. Describes the treatment of monazite sand with sulphuric acid to obtain an insoluble thorium compound, the latter being directly converted into thorium hydroxide. The process is described in connection with Indian monazite, which has been concentrated by magnetic separation of ilmenite.

CALCINED MAGNESITE.—R. D. Pike (*Pat. J.*, 1749, 1922). No. 180,837 Apr. 6, 1921. Magnesite containing a small quantity of limestone or dolomite is calcined, and the resulting content of relatively soluble lime is carborated by treating with a gas containing CO_2 and a trace of water vapour, without affecting the magnesia, to give a calcined magnesite suitable for the manufacture of oxychloride cement. Suitable apparatus is described.

DECOLORIZING KAOLIN, ETC.—A. J. Stubbs (*Pat. J.*, 1750, 1922). No. 181,132, Mar. 12, 1921. Kaolin, barytes, felspar, bauxite, etc., are decolorized by suspending the finely divided minerals in water, to which are added pieces of platinum, iron or zinc. SO_2 is then introduced and is reduced by catalytic action to hyposulphurous acid, liberating oxygen, which renders the colouring matter soluble in the hyposulphurous solvent. The colouring substances may be precipitated by lime or an alkali, for use as pigments.

MAGNESIUM CHLORIDE.—Aktiesel. de Norske Saltverker (*Pat. J.*, 1751, 1922). No. 181,375, Anhydrous magnesium chloride is prepared by the action of chlorine on a mixture of magnesium oxide and carbon at a temp. below the melting point of mag. chloride, the materials being perfectly dry and the carbon free from gas.

PHYSICAL AND CHEMICAL PROPERTIES, TESTING, ETC.

NOTE ON THE HYGROSCOPICITY OF CLAY AND THE QUANTITY OF WATER ABSORBED PER SURFACE UNIT.—Sven Odén (*Trans. Far. Soc.*, **17**, 244, 1922). The amount of hygroscopically-bound water in clays and soils is dependent on the vapour pressure of the water in the air

as well as on the nature of the soils in question. The writer tested a number of clays in a large desiccator containing a sulphuric acid—water mixture, the vapour pressure being taken by Regnault's measurements. A characteristic curve is obtained for each clay, if the retained amounts of water are plotted against the corresponding vapour pressures. The coarser the clays are, the less water is held. By a method of studying the rate of sedimentation in a clay slime, and its variations during the time of sedimentation, the author obtains a measure of the order of magnitude of the total surface area which the particles represent on the fall through the liquid. It is shown that calculation backwards from hygroscopicity to surface development of a soil is fallacious.

COLLOIDAL CLAY IN SOAP.—F. E. Weston (*China Rev.*, **4**, 480, 1922). As the result of experiments, it was found that the addition of colloidal clay improved the qualities of soaps generally.

INVESTIGATIONS ON ARTIFICIAL AND NATURAL GRAPHITE.—K. Arndt and F. Körner (*Zeits. angew. Chem.*, **35**, 440, 1922). Figures are tabulated to show that the electrical resistance increases as the size of the particles decreases.

THE EFFECT OF VANADIUM ON CERAMIC RAW MATERIALS AND PRODUCTS.—O. Kallauner and I. Houda (*Sprech.*, **55**, 333, 1922). The available literature on the subject is first mentioned briefly. Experiments were conducted to determine the effect of vanadium, (1) on the melting-points of Zettlitz kaolin; (2) on the colour of dried test pieces, fired both under oxidising and reducing conditions; (3) on the blistering tendency in kaolin and a typical brick clay. The results show that vanadium pentoxide lowers the melting point of kaolin, more or less in proportion to the quantity present. But the small amounts usually found in ceramic raw materials have practically no effect on the m.p. To produce the characteristic yellowish colour, either at normal temp. or in the fire, not less than 0·1% of vanadium pentoxide or potassium vanadate must be present. This defect can be counteracted by the addition of barium compounds (nitrate or carbonate). Seger's statement, that a reducing atmosphere has the effect of lowering the tendency to blistering due to vanadium, was confirmed. In some cases, and at certain firing temperatures, blistering was considerably decreased, and occasionally entirely eliminated, by the addition of substances which form insoluble compounds with the soluble vanadium compounds, *e.g.*, barium and calcium compounds.

THE COMPOSITION AND MICRO-STRUCTURE OF CLAYS, THEIR FUSIBILITY AND THE TRANSFORMATIONS WHICH THEY UNDERGO AT HIGH TEMPERATURES.—L. Bertrand and A. Lanquine (*Cer.*, **25**, 97, 1922). The examination of a large number of samples under the polarising microscope showed that, with the exception of clays coming from the immediate vicinity of micaceous rocks, an appreciable quantity of mica flakes was met with only in exceptional cases, in spite of an alkali content of 2% and over, which would imply a mica content of 20% and more. Microscopic investigation, therefore, has demonstrated that the current method advocated by well-known writers (the so-called rational interpretation of chemical analyses), according to which the mica content of a clay is calculated on the basis of the alkaline determined by the analysis, must be abandoned. The two types of clays, halloysite and kaolinite, represent two distinct physical states, the relationship $2SiO_2:Al_2O_3$ being practically constant in both. Furthermore, it does not appear possible to distinguish between them by the degree of hydration. There appears to be no relation between the leanness or fatness, of a clay and the respective proportions of SiO_2 and Al_2O_3 which it contains. *Fusibility*. Figures are quoted of experiments on 101 clays, showing that the alumina content of a clay is by no means the only factor determining its fusibility.

THE CHEMICAL COMPOSITION OF ALKALI FELSPAR.—K. Seto

(*J. Jap. Cer. Ass.*, 343, 237; 344, 269, 1921). The analyses of felspars hitherto published do not always agree well with their optical constants, probably owing to the difference between samples. To make up this deficiency, the same crystals whose optical properties had been determined by Prof. Kozu, of the Tohoku Imperial University, were analysed as accurately as possible. The samples include albite of Alp Rishuna, orthoclase of Madagascar, moonstone of Ceylon, adularia of St. Gothard, and of Riedertobel and a native perthite. The composition of the perthite which is produced at Kutsuwatori, near Ishikawa, Fukushimaken, is as follows: 65·44% silica, 19·55% alumina, 0·05% ferric oxide, 0·12% magnesia, 0·49% lime, 3·77% soda, 10·78% potash, 0·18% loss on ignition and 100·38% in total. The mineral composition of the perthite is, therefore, $Or_{63\cdot8}$ $Ab_{33\cdot7}$ $An_{2\cdot5}$. The mineral is used in potteries. S. KONDO.

THE ACTION OF HEAT ON REFRACTORY CLAYS; AND THEIR RATIONAL ANALYSES.—K. Fuha (*J. Jap. Cer. Ass.*, 351, 566, 1921). The investigation was carried out with the object of getting full knowledge on clays used in the manufacture of pots for optical glass. The solubility of six clays in boiling conc. hydrochloric acid, and the analyses of the solutions and residues are described. Solubility ranged from 23 to 75% when boiled for one hour and a half, and 93–96% on boiling for twenty-four hours. Lime and magnesia were almost completely dissolved. The loss on heating at various temperatures is described. The temperatures at which the weight of the Japanese clays decreases most rapidly are 400°–500°C. The solubility of seven clays previously heated at various temp., in boiling hydrochloric acid is discussed. The result, in short, confirms that of A. N. Sokoloff in 1912. The methods of rational analysis and its published discussions are described. Clay, heated up to 800°C. may be used for rational analysis; there were remarkable differences in the amounts of residues between clays heated at 1,000° or 1,100°, and those heated at 1,200°. This increase is due to alumina and silica, their ratio in equivalents being about 1 : 2. S. KONDO

STUDY OF GYPSUM.—K. Kishimoto (*J. Jap. Cer. Ass.*, 357, 201, 1922). The results of experiments, in which one gram of a pure gypsum was heated in an electric furnace at various temperatures for different periods, indicate that the mineral loses its water when it is heated at 90°C. or higher, but the rate is very slow at 90°. Soluble anhydrite is strongly hygroscopic and changes readily to the hemihydrate in the atmosphere. The hemihydrate takes moisture from the atmosphere; this phenomenon is merely due to physical adsorption. S. KONDO.

II.—MANUFACTURING PROCESSES:

GENERAL.

NEW STUCCO LATH MADE OF BURNED CLAY.—(*Brick*, **60**, 995, 1922). Richholt Bros., of Holgate, Ohio, have patented a new product in the form of slabs 8″ wide by 12″ long by $\frac{5}{8}$″ thick. These slabs are perforated to permit nailing to the wall with large-headed galvanized nails. They are made on a hollow tile machine in the form of hollow blocks, the corners of which are cut to a certain depth to facilitate breaking the block into four slabs after burning. No special machinery is required.

MODERN TILE MAKING; I.—A. B. Searle (*Brit. Claywr.*, **31**, 72, 1922). A short historical introduction is followed by sections on: The nature of clay, Plasticity, Binding power, Origin of clays, and Nature of clay deposits.

THE MAKING AND BURNING OF GLAZED WARE: I.—(*Brit. Claywr.*, **31**, 77, 1922). The first of a series of articles intended to form the *vade mecum* for those with some practical experience in fireclay works. It includes sections on: The body of the ware; Fireclay characteristics; Lime and ironstone; The presence of iron and cupriferous pyrites.

REFRACTORY BLOCKS FOR GLASS TANK FURNACES.—(*Brit. Claywr.*, **31**, 79, 1922). The manufacture of blocks is discussed from the

point of view of their principal requirements : (1) refractoriness ; (2) strength ; (3) resistance to sudden changes of temp. ; (4) uniform corrodibility, and their use in different parts of the furnace.

DRAIN PIPES.—(*Kalk. Schm.-Ztg.*, **29**, No. 8, 1922). The general process of manufacture is discussed. Drain pipes for draining agricultural land were first used in England. The method was then introduced into Germany, and has since become widely applied.

THE MILLING AND PREPARATION OF RAW MATERIALS IN THE EARTHENWARE INDUSTRY.—B. Wilde (*Ker. Rund.*, **30**, 167, 1922). A discussion of general works problems.

NOTES ON THE PREPARATION AND IMPROVEMENT OF THE RAW MATERIALS IN TIN-GLAZED EARTHENWARE. A. Cornille (*Rev. Mat. Constr. Trav. Pub.*, No. 150, 35B, 1922).

ON THE MANUFACTURE OF FIRE-PROOF KITCHEN WARE.—F. Bigot (*Rev. Mat. Constr. Trav. Pub.*, No. 151, 53B, 1922). As regards quality, kitchen ware should satisfy two conditions : (1) it should be sufficiently refractory, and (2) should not impart a disagreable flavour to foods cooked in it. Under (1), the chief property required is the ability to resist sudden variations of temp., which depends upon such factors as conductivity, porosity, cohesion, the form of the constituents, the arrangement of the particles, etc. If a body composed of a siliceous clay and magnesium carbonate is fired to a high temp., it comes out porous owing to the escape of CO_2. When exposed to the fire, such a body falls to pieces. But if the same body is ground finely, formed under mechanical pressure, and again fired, it will show remarkable refractory properties. Both conductivity and porosity, therefore, have a direct influence on the fire-resisting property of a body. If this property is due mainly to the conductivity of the body, allowance must be made for the internal stresses set up when in contact with fire, and the manufacturer will do well to fire the body to the temp. which brings about the best possible combination of the constituents *without* causing vitrification. Certain old types of pottery examined showed a foliated structure, consisting of innumerable "flakes" which are capable of movement, one over the other, thus equalizing stresses. No satisfactory explanation of the second point—flavouring effect on foods—is yet forthcoming. The writer thinks it is due to the phenomenon of capillarity, the *form* of the capillary voids constituting an important factor. Fats and liquids, which to a greater or less degree have become imprisoned in the voids, contaminate foods subsequently cooked in the utensils.

THE MANUFACTURE OF FIRECLAY CRUCIBLES.—(*Ker. Rund.*, **30**, 107, 1922. Very special care is necessary in preparing the body for fireclay crucibles, if they are to withstand the cooling stresses successfully. The most important factor in the body is undoubtedly the ball clay, which should be as fat as possible so as to counteract the effect of the shortening materials added and to bind them effectively. At the same time, it should not shrink excessively. The refractoriness of the clays employed should correspond roughly to Cone 32. Clays which sinter at a comparatively low temperature (Cones 2a to 6a), but which, when mixed with clay grog, do not vitrify at higher temperatures are particularly valuable, since they are not sensitive to changes of temperature. The preparation of the clays depends upon their raw condition. Hard, stiff clays are placed in small heaps and allowed to weather. The clay is then broken up, screened, and mixed in a pug-mill with from 30 to 40% of grog which has previously been freed from powder by sieving. The resulting somewhat stiff body is formed into lumps, which are dried, ground, and again treated as before. The powdered body is spread out in thin layers on trays, moistened uniformly with water, and then forced through a coarse mesh.

Softer clays require less preparation ; weathering may be dispensed with. They are mixed with grog (as above), moistened and screened. The stiff

paste is then formed into lumps which are covered with damp cloths and stored in cellars as long as possible, so as to produce a uniformly moist and plastic body. Immediately before use the lumps should be beaten out, or passed through the pug-mill again, to render the mass uniformly dense. When formed, the crucibles must be very slowly and thoroughly dried in a slowly-rising temperature. They should preferably be fired very cautiously to Cone 8–9.

Patents.

TILES.—G. Maddalena (*Pat. J.*, 1732, 1922). No. 174,603, Jan. 24, 1922. Asbestos-cement tiles are coated with a thin layer of limepaste and marble powder and ironed. A second layer of a mixture of milk of lime and soda-free soap solution is applied and ironed with a very hot iron. The tiles are water-proof and fire-proof.

TEA-POTS.—A. P. R. Willis (*Pat. J.*, 1732, 1922). No. 174,886, June 2, 1921. To prevent dripping, the spout is provided with a metal cap or lip, with a central groove and sharp point.

SOUND-MAGNIFYING HORNS OF BAKED CLAY.—W. F. Smith (*Pat. J.*, 1744, 1922). No. 178,944, Jan. 26, 1921. The inner surface of a sound magnifying horn, made of baked clay, is left unglazed and minutely granular.

COMPOUNDING AND PREPARATION OF BODIES, ETC.

Patents.

PROCESS OF MANUFACTURING GRANITE-PORCELAIN.—Tomotaro Kawamoto and Gosuke Kato. (*Jap. Pat.* No. 40,582, November 9, 1921). A porcelain is made of a body which is prepared by mixing coarse grains of granite with the other ingredients, *i.e.*, felspar, quartz, amalgatolite, Kibushi clay, limestone and water. The fired products look like granite. S. Kondo.

PROCESS OF MANUFACTURING TALC POTTERY.—Kosuke Hirano (*Jap. Pat.* No. 40,963, November 30, 1921). Magnesite, calcined at 600°–1,200°C., is added to the body materials of talc pottery. In most cases, the talc is previously heated at a high temperature. S. Kondo.

PROCESS OF MANUFACTURING LIGHT BRICK.—Kinji Katada (*Jap., Pat.* No. 41,372, January 11, 1922). Bricks are formed with a body which is prepared by mixing and kneading coarse grains of coal-cinder, containing 25–35% of combustible carbonacious substances, saw-dust and fire-clay. They are afterwards fired in a kiln. S. Kondo.

SHAPING, MOULDING, DRYING, ETC.

ON DRYING WALL TILES.—G. Steinbrecht (*Ker. Rund.* **29**, 450, 1921; **30**, 13, 1922). The writer was invited to investigate the cause of an abnormally high breakage in a biscuit oven. It was discovered that the root of the trouble lay solely in the treatment of the ware after pressing, and particularly in the drying process. The latter was carried out in two sheds measuring about 12×3 yards and 8 ft. high. The entrance was in one of the front walls, and, near to it, the stoke hole was situated a little below the level of the floor. The heating flue, constructed of grog bricks (half brick thickness) ran along one long side, underneath the benches, through the opposite wall into a store room and from there to the stack. The ventilation arrangements were totally inadequate. Three small openings, measuring only 4″ by 4″, were situated in, or near, the roof, and these were usually closed "to keep the heat in." There were no air *inlets* of any kind. To produce natural ventilation, the following alterations were carried out: An opening measuring 15½″ by 17½″ was constructed in the front wall over the grate, and fitted with a shutter and grating. The object of the grating was to dissipate the cold air entering from the outside and thus ensure a more thorough mixing with the warm air in the shed. Two of the small openings in the roof were closed; the third, in the back wall under the roof, was enlarged to about 14″ by 14″.

Over this was constructed a 16-foot ventilator shaft, fitted with a shutter. In order to get rid of the moist air which collected under the roof at the opposite end, a hole 6 inches square was made in the front wall just under the roof ; this produced a natural draught towards the ventilation shaft. Finally, the brick heating-flue was replaced by two refractory pipes resting on small iron trestles. A greater quantity of heat was radiated from these pipes owing to their thinner walls and larger surface area. With the new drying method in operation, the drying period was reduced from about 16 to 8 days,, with less fuel consumption, and the breakage was reduced from round about 70 per cent. to 50 per cent. To demonstrate clearly the importance of a proper system of ventilation, glass plates were built into the back wall of each chamber. When all the shutters were closed, water rapidly condensed on these plates, showing that the air had become saturated with moisture ; upon opening the ventilators, they soon became dry again. Hygrometers and thermometers were placed in each drying chamber. With the aid of these instruments and a table, showing the quantity of moisture contained in one cubic centimetre of air when in a saturated condition, it was possible to determine the water-absorbing capacity of the air in the sheds for any given temperature. But with the breakage figure still standing at about 50 per cent., the conditions were far from satisfactory, and the treatment of the raw pressed tiles was next investigated. After leaving the filter presses,, the body was treated in the usual way. The mistake was made in stacking the raw pressed tiles. From 6 to 10 of these were placed on burnt slab and covered with a similar slab to prevent warping. Two concentric circular impressions were made on the back of each tile, with the object of giving the mortar a better grip. Stacked in this manner, the tiles obviously could not dry properly, since they were lying almost one upon another, and the moisture in the middle was unable to escape ; and the circular impressions were nothing but collecting centres for this moisture. To give the centre portion of the stacks access to the air while drying, the press was altered so as to form long straight grooves running throughout the length and breadth of the back of the tiles. The "swallow-tail" pattern was also introduced. Experience showed that drying was best effected by allowing the fresh tiles to remain in the shed for about 48 hours without firing and with full ventilation. Firing was then begun and the temperature gradually brought up to 100°F. during the following 48 hours, with the grating in position and both shutters partially closed to the extent of one-third. In cooling, the grating was removed and the shutters opened as soon as the outside temperature was reached, so that the whole process occupied from 7 to 8 days. It is pointed out that it is a fundamental mistake to introduce fresh ware into a drying chamber which already contains some dry or partially dried ware. It is, therefore, much more advantageous to have a number of small chambers rather than one large one.

Patents.

MOULDING EARTHENWARE, ETC.—W. A. van Dijk (*Pat. J.*, 1732, 1922). No. 174,918, Jan. 16, 1922. The prepared slip is introduced, into a rotating mould having recesses corresponding in shape to the required articles.

MOULDING INSULATING BEADS, ETC.—Taylor, Tunnicliffe & Co., and P. Cooper (*Pat. J.*, 1733, 1922). Pierced articles, *e.g.*, insulating beads, are formed from plastic, semi-plastic or powdered substances by moulding in dies in a press, the die in which the mould recesses are formed being detachable from its support.

HIGH-TENSION INSULATORS.—Meirovsky & Co. (*Pat. J.*, 1739, 1922). No. 177,499, Feb. 24, 1922. The electric strain in a longitudinal direction is reduced by embedding very fine conducting wires or strips in the insulators. Crowding of the equipotential surfaces in the neighbourhood of the flange is avoided.

TILES.—J. and J. W. Moss and G. H. Downing (*Pat. J.*, 1742, 1922). No. 178,212, Jan. 17, 1921. A system of projections and recesses on the face

of roofing tiles is described. The tiles have inverted V-projections on the upper portion and the lower edge is inclined or bevelled.

MOULDING CONCRETE BUILDING-BLOCKS.—J T. Browne and W. Black (*Pat. J.*, 1742). No. 178,370, July 7, 1921. Relates to a method of casting a concrete building-block consisting of two vertical slabs united by metallic ties.

DRYING POTTERY.—T. Poole (*Pat. J.*, 1,744, 1922). No. 179,066, Apr. 18, 1921. A drying stove consists of a casing of wood with small door, and contains a steam-heated radiator arranged vertically at the centres. Endless conveying chains pass over sprocket wheels, carrying cages or shelves. The drive is effected by a hand operated shaft and worm gearing for each pair of chains and wheels.

ELECTRIC INSULATORS.—A. Renaudin (*Pat. J.*, 1745, 1922) No. 179,180/1. Feb. 18, 1921. A description of a special shape and of a method of connecting in series by wire ligatures.

CHIMNEY POTS.—R. H. Smith (*Pat. J.*, 1747, 1922). No. 180,200. A tubular length of clay is expanded on a tapering core within a mould. Clay is forced through a shaping space between a fixed core and a fixed die, which is attached to the upper end of a mould.

BRICKS FOR ARCHES.—Humphreys & Glasgow, Ltd. (*Pat. J.* 1,754, 1922). No. 182,572, Apr. 7, 1921. Relates to a special shape. The top and bottom of the bricks taper in the direction of their length, the ends taper from the bottom towards the top, and one end portion is offset from the other end portion to form steps in the top and bottom.

TEAPOTS.—W. Sherwood (*Pat. J.*, 1,754, 1922). No. 182,703, July 27, 1921. To facilitate rinsing out, the body of a teapot is formed of a concave or rounded shape, and the lid registers with a considerable portion of the back surface.

PROCESS OF FORMING CLAY IMAGES.—Eizaburo Murakoshi (*Jap. Pat.* No. 39,732, August 30, 1921). Clay images, imitating ancient "Haniwa," are formed with plastic clays, using a cloth bag filled with sand as a core, which is taken out afterwards by discharging the sand. The images are then fired in a kiln. S. KONDO.

KILNS, OVENS, MUFFLES; FIRING TECHNIQUE, ETC.

THE LENGTH OF THE FIRING ZONE IN ANNULAR KILNS.—K. Dümmler (*Deut. Töp. Zieg. Ztg.*, **53**, 212, 1922). With a short firing zone, a much larger volume of air than is theoretically necessary has to be passed over the ware in order to effect a transfer of the heat. With a long firing zone, it is possible to increase the output, since fresh lots can be taken over every 4, or even every 3 hours, instead of every 6 hours. In general it may be assumed, that an annular kiln is working most efficiently when approximately 12% of its length is charged and discharged daily, 12% is used for smoking, 16% for preheating, 16% for burning, 20% behind the fire, 8% for conducting the heat to the smoking section, the remaining 4% being empty.

FLUE GAS ANALYSIS IN CEMENT KILNS.—A. Heiser (*Tonind. Ztg.* **46**, 831, 1922). A theoretical discussion.

ON FIRING DUTCH CLINKER.—P. Thor (*Tonind. Ztg.*, **46**, 850, 1922)

HEAT ECONOMY INVESTIGATIONS OF SAND-LIME BRICK WORKS.—Eberle (*Tonind. Ztg.*, **46**, 863, 1922). The paper deals mainly with the production of steam for power and hardening purposes.

AN IMPROVED DESIGN OF TUNNEL KILN.—(*Brit. Claywr.* **31**, 116, 1922). An illustrated description of the Tongres kiln (*v.* p. 68).

MODERN METHODS OF TREATING LIGNITE AND ITS DERIVATIVES.—Ch. Berthelot (*Chim. Ind.*, **7**, 1079, 1922).

THE INFLUENCE OF THE TEMPERATURE OF THE SMOKE GASES ON THE DRAWING CAPACITY OF A CHIMNEY.—M. Laffarque (*Chim. Ind.*, **7**, 1099, 1922). On raising the temp. of the gases in a chimney, the pull, or efficiency of the latter will increase to a certain maximum, after which it decreases. An important point is to determine the temperature limit which gives the maximum efficiency. Industrially, the problem becomes : To what extent may smoke gases be cooled down before passing to the stack ? This is briefly discussed.

SCALE FORMATION AND CORROSION IN BOILERS.—A. A. Pollitt (*Chem. Age.*, **7**. 76, 1922). The effect of the impurities commonly occurring in boiler feed-water is discussed, and a description is given of the corrosive reactions which are responsible for the deterioration of plates and tubes.

THE INFLUENCE OF EXCESS AIR ON THE EFFICIENCY OF BOILER FIRES.—J. Seigle (*Rev. Ind. Min.*, No. 31, 171, 1922). It is often assumed that the loss of heat through the chimney increases directly in proportion to the amount of excess air employed to effect combustion of the fuel. But the temperature of the smoke gases diminishes more or less as the excess air increases in volume. An attempt is made to determine the loss of calories through the stack when the CO_2 content varies owing to a greater or smaller volume of excess air. It is shown that the effect of an economiser behind the grate is greater, *ceteris paribus*, when firing is conducted with a large excess of air. It is also shown that firing with large excess of air for short periods has a much more serious effect than a mere consideration of the average CO_2 content would lead one to believe.

AN OUTLINE OF EFFICIENT FIRING RECORDS.—J. H. Kruson (*Brick*, **60,** 921, 1922). The need of good burning apparatus (draught gauges, pyrometers, cones, etc.) is emphasised. A general outline of the burning record, comprising some 30 sub-divisions, is given. The information derived from such a record, if accompanied by draught and temp. records, etc., will supply all that is required for effective control. Four charts are illustrated.

THE INFLUENCE OF STRUCTURE ON THE COMBUSTIBILITY OF SOLID FUELS.—E. K. Sutcliffe and E. C. Evans (*J. Soc. Chem. Ind.*, **41,** 198T 1922).

GAS FIRING.—J. W. Mellor (*Brit. Claywr.* **31,** 81 1922). The main object of the paper is to show that no saving of fuel is effected when the best of the continuous firing systems and gas firing are fairly compared. Roughly 30% of the heating value of the fuel is lost in conveying the gas from the producer to the burners. The Woodall-Duckham portable producer, which was constructed to overcome this difficulty, is mentioned. Uniform distribution of heat is difficult to attain in gas firing. A promising solution is the Woodall-Duckham kiln (4 diagrams), which has a central burner, and in which the upward streams of burning gases divide and spread laterally and downward. The advantages of gas firing are : better regulation of the supply of secondary air and fuel ; better control of temperatures and kiln atmospheres ; it is cleaner to use.

DRAUGHT IN ANNULAR KILNS AND SMOKING WITH WASTE HEAT.—P. Thor (*Deut. Töp. Zieg. Ztg.* **53,** 229, 1922). A short general discussion.

ON BURNING LIME AND BRICKS IN ONE AND THE SAME KILN.—Baschant (*Deut. Töp. Zieg. Ztg.*, **53,** 231, 1922). On the basis of a long experience, the writer claims that it is possible and even advantageous to burn lime and bricks simultaneously in an annular kiln.

LARGER CONTINUOUS KILNS.—(*Brick Pot. Tr. J.*, **30,** 135, 1922). One large kiln is better than two separate kilns, of half the size, for if one of the latter is not used, it will rapidly deteriorate, whereas a large kiln will always be in use and will be well preserved. A large, or "double-sized"

kiln has two separate fires and burning zones operating independently. No kiln with two fires should have less than 24 chambers, or a total length of at least 624 ft. A kiln of 20–22 chambers is best worked with one fire. A kiln of 12 chambers, total length 156 ft., is too short to enable the goods to be pre-heated and cooled slowly, and some heat is lost. To double the length of such a kiln, using two firing zones, does not improve the quality of the ware, though the output may be doubled with care. A further number of chambers should, therefore, be added to aid the control. With fan draught, and a sufficiently long kiln, the output can be increased by very rapid burning, as is done in some tunnel kilns and in the Bührer kilns.

BURNING HOLLOW TILE IN DOWN-DRAUGHT KILNS.—C. P. Ellis (*Claywr.*, **77**, 551, 1922). The three stages—water smoking, oxidation, and heating up—are described in some detail. The average time for burning in down-draught kilns is about 72 hours. The use of a pyrometer is essential. When working with unknown materials, water smoking may take several days. A curve sheet for recording the progress of a burn is illustrated.

AN IMPROVED FORM OF GAS-ANALYSIS APPARATUS.—E. W. Blair and T. S. Wheeler (*J. Soc. Chem. Ind.*, **41**, 187T, 1922). The new type is an improved form of the Bone-Wheeler apparatus. Compressed air and a vacuum are used to alter the mercury levels, thus saving much of the labour involved in raising and lowering the mercury through about twice the barometric height. The apparatus is much more compact.

THE DANGERS OF POWDERED FUEL.—A. B. Helbig (*Feuerung*, **10**, 188, 1922). With ordinary precautions, and with proper understanding of the process, and of the properties of the material, firing with powdered fuel is no more dangerous than other normal industrial operations.

MUFFLES: THEIR PROPERTIES AND CONSTRUCTION.—(*Rev. Mat. Constr. Trav. Pub.*, No. 152, 75B, 1922).

AN ELECTRICAL APPARATUS FOR ANALYSING GASES.—M. Moeller (*Brennstoff-Chemie.*, **3**, 190, 1922,; *Stahl Eis.*, **42**, 982, 1922) The new instrument depends upon the varying thermal conductivities of different gases. Relative to air (= 100), the figures are: Hydrogen 700, nitrogen 100, oxygen 101, CO_2 59, CO 96, sulphurous acid 34. The temperature of a wire heated by an electric current depends upon the conductivity of the gas surrounding the wire. By a suitable choice of wire material, this difference in temp. is expressed in the form of varying resistance. Two thin wires, one in air and the other in the gas under investigation (flue gas etc.), are heated electrically and the difference in resistance is measured and recorded.

A SYSTEMATIC STUDY OF CERAMIC KILNS.—P. Frion (*Cer.*, **25**, 158, 1922). A paper read before the general meeting of the Syndicat des Fabricants de Produits céramiques de France, outlining the progress made in (1) improving combustion; (2) utilising the available heat; (3) reducing heat losses; (4) utilising different fuels.

ON FIRING PORCELAIN WITH MAZOUT (PETROLEUM RESIDUE).—A. Granger (*Cer.*, **25**, 167, 1922). Mazout is the Russian name given to the naptha residue after separating the kerosene from petroleum. It is dark brown in colour, of a tarry appearance and moderate fluidity. The writer describes the method of firing and the results obtained in a small furnace of 3 cu. m. capacity.

HEAT LOSSES IN FURNACE CONSTRUCTION.—W. Ritter (*Feuerung*, **10**, 176, 1922). Deals with electric furnaces. Silica and magnesia bricks, though highly refractory, are not good insulators. Ordinary red bricks and the so-called insulation bricks are fairly good insulators, but kieselgur bricks are by far the best. A thin coating of specially prepared asbestos improved the insulating properties of a refractory brick very considerably.

INCOMPLETE COMBUSTION AND FIRING CONTROL.—Haarmann

(*Feuerung*, **10**, 173, 1922). The formulæ used to arrive at the necessary data are discussed in some detail. Registration of the CO_2 content is not sufficient for controlling the firing operations. Continuous examination of the gases of combustion for unburned gases is essential. Periodic determination of the O_2 content, in order to estimate the volume of unburned gases from the sum of CO_2+O_2, is not sufficient.

AN INTERESTING TYPE OF GENERATOR.—(*Verre*, **2**, 97, 1922). A description of the Chapman gas generator. The data necessary to establish comparative thermal balance sheets are tabulated.

GAS GENERATORS FOR THE GLASS INDUSTRY.—H. Nowotny (*Sprech.*, **55**, 264, 1922). An improved Morgan generator is described, with central and peripheral blowers. The improved apparatus has a coal capacity of 9,000–10,000 kg. per 24 hours. Two such generators replace 3 of the ordinary Wilson type, so that the cost of reconstructing the latter is rapidly recuperated by a saving of manual labour.

DRYING AND PULVERIZING RHINELAND BROWN COAL.—(*Ker. Rund.*, **30**, 237, 1922).

ON FIRING BRICKS, ETC.—K. Dümmler (*Deut. Töp. Zieg. Ztg.*, **53**, 43, 1922). A paper read at the Municipal Brick-makers' School, at Frankfort-on-Oder. The speaker gave a general survey of the subject, and dealt finally with the "Vesta" system of firing with peat.

THE VESTA SYSTEM OF FIRING ANNULAR KILNS.—Günther (*Deut. Töp. Zieg. Ztg.*, **53**, 186, 1922). A short account of some practical results obtained with the Vesta method of firing with peat.

CAN BRICKS BE FIRED WITH COAL-WASHINGS?—(*Deut. Töp. Zieg. Ztg.*, **53**, 160, 1922). In the Westphalian coal district satisfactory results are obtained in annular kilns with a mixture of coke and coal washings. Coal washings might also be mixed with the clay to produce a light brick.

BURNING SHALE BRICKS.—L. B. Rainey (*Brick*, **60**, 693, 1922). The various stages of burning, production of colours, reduction of scum, the value of pyrometry and cones, and the speeding up of kiln turnover are discussed.

NEW COLLOIDAL FUEL.—(*Brit. Claywr.*, **31**, No. 360, 18, 1922). Crude fuel oil is mixed in definite proportions, with finely ground coal (88% and more passing a 180-mesh). The fuel is fired like ordinary oil fuels. It gives all the advantages of oil firing at a cost approximating to that of coal. There is no smoke, no clinker and no ash. Experiments were carried out at the works of Coal, Peat and Oil, Ltd., Earlstown.

A NEW CHAMBER KILN FOR BLUE BRICKS.—(*Brit. Claywr.*, **31**, No. 360, 21, 1922). A description of the new kiln installed at the works of Stoneware, Ltd., Dosthill, near Tamworth.

THE ADAPTABILITY OF THE GAS-FIRED COMPARTMENT KILN FOR BURNING CLAY PRODUCTS.—W. D. Richardson (*J. Amer. Cer. Soc.*, **5**, 254, 1922). By a compartment kiln is meant a series of kilns in juxtaposition, separated by a common wall and connected with each other by openings in the walls above or below the floor level, the kiln being in continuous operation; the air for combustion is heated by passing through compartments of the fired ware behind the fire and the hot gases of combustion and passed through the compartments ahead of the fire to preheat the ware. Producer gas can be conducted to any part of a compartment and in any quantity, and its combustion can be controlled, so that any desired temperature may be reached quickly and oxidizing or reducing conditions maintained at will. As no ash is deposited on the ware and no flame need strike it, no protection for the ware is needed. The kilns operated by the writer in burning high-grade face bricks, had compartments of such size that they could be filled by one gang of setters (two tossers and two setters) in two working days. This meant that one compartment had to be fired every two days. The compartments were two-side firing, 18 ft. wide, 43 ft. long and 10 ft. high.

On completing the firing of one compartment, the next adhead would be red hot to the bottom and the second incandescent half way, and sometimes completely, to the floor. Simultaneously with this system of firing, the same type of brick was also burned by direct firing in periodic kilns, so that accurate comparison was possible. The producer-gas-fired compartment kiln required less than half the amount of coal consumed in the periodic kilns, and, moreover, gave much more uniform results. The installation of a compartment kiln does not necessitate greater cost of handling, but merely a different system. Instead of the ware being carried by the kiln drawers to the next compartment, it must be placed by them on trucks or cars or continuous conveyors. The advantages of a continuous gas-fired compartment kiln may be summarised as follows : (1) a saving of 60 to 70 per cent. of the fuel used in periodic kilns ; (2) a more compact kiln plant, with less waste of space in the factory ; (3) no coal or ashes distributed round the plant. Mechanical unloading of coal and removal of ashes at one place ; (4) more rapid firing. No fuel is introduced into a compartment until it is red hot throughout. The heat from combusted gases is utilized to the fullest extent for preheating purposes ; (5) better control of the burning, as compared with periodic kilns, gas and air being regulated at will ; (6) greater uniformity of heat distribution, more uniform product ; (7) Less cost for repairs than the periodic kiln, and the advantage over the car tunnel kiln that repairs can be done without serious interruption of the operations ; (8) lower operation costs per ton of ware fired ; (9) greater flexibility and adaptability—greater variety of ware—as compared with tunnel kilns. The firing can be hastened or slowed down as required ; (10) the lower height of the bungs and the absence of abrupt rises in temp. increase the life of saggars ; (11) no sulphuring of goods, pure hot air from cooling chambers being used for preheating. The writer concludes that although no single type of kiln is the best for all products and conditions, yet the compartment gas-fired kiln has a wider range of practical utility than any other type.

HOW TO PREVENT SMOKE FROM POTTERY KILNS.—S. Momoki (*J. Jap. Cer. Ass.*, 349, 474, 1921). A social question is now arising on this subject in some districts of the country. The author has long been investigating various methods of preventing smoke from kilns firing faience and porcelain. They are discussed in detail : (1) Electrical precipitation is too expensive ; (2) use of pulverised coal is probably injurious, as the best domestic coals contain 10–20% of ash ; (3) firing with heavy oil is too expensive ; (4) experiment with Kraft's mechanical stoker has shown good results for faience, fired at Cone 7 ; but the need of even-grained coal and the excessive burning-out of metallic parts, make its use for hard fire porcelain doubtful ; (5) methods of consuming flue gases by the introduction of hot secondary air, such as P.A.F. Schultz's patent, are promising ; but their application o old kilns is expensive or inconvenient ; (6) gas firing with the pressure-gas producer is probably better than the methods described above ; (7) use of tunnel kilns is most promising ; but gas firing and the use of tunnel kilns need ample space of which some factories are devoid. S. KONDO.

ON TUNNEL KILNS.—S. Momoki (*J. Jap. Cer. Ass.*, 347, 385, 1921). Although small tunnel kilns have been used for over-glaze coloring for more than ten years in Japan, Mr. K. Okura, president of the Toyo-Toki Co., was the pioneer in adopting large tunnel kilns for hard firing. In August, 1920, a Dressler tunnel kiln was completed at their factory. The result of seven month's experiment was quite satisfactory. As to the saving in fuel, 315 lbs. of second class lump coal of Kyushu were required for heating one car load of sanitary ware, measuring 70 cubic feet, to Cone 6, while six-metre round kilns of the English style consumed 875 lbs. of the same coal in firing the same volume of saggars to the same temperature. Conclusions are (1) that the building cost of a tunnel kiln is about three times as much as round kilns of the same capacity ; (2) that the kiln house for round kilns costs twice as much for faience, and two and a half times as much for porcelain, as the tunnel kiln ; (3) round

kilns require about double the space, compared with tunnel kilns, for faience, whereas the ratio is just reversed in porcelain works and (4) also that the excess of fixed capital in the erection of tunnel kilns is outweighed by its general advantages, and accordingly it reduces the cost of production by the saving in fuel and the utilization of waste heat. S. KONDO

EXPERIENCES WITH ROTARY KILN LIME BURNING.—I. Warner (*Rock Prod.*, **25**, No. 15, 17, 1922).

THE ANALYSIS OF SMOKE GASES IN CEMENT FURNACES.—(*Tonind. Ztg.*, **46**, 929, 1922). A theoretical discussion.

THE THERMAL BALANCE OF A COAL-FIRED TUNNEL KILN.—F. Pr. (*Rev. Mat. Constr. Trav. Pub.*, No. 153, 81B, 1922). A résumé of work published by various authors.

THE HEAT CONTENT OF WASTE GASES.—C. Schwarz (*Feuerung*, **10**, 245, 1922). A theoretical discussion.

ELEVEN YEARS OIL-BURNING EXPERIENCE.—M. A. Taylor (*Brick*, **61**, 246, 1922). The relative merits of the various types of fuel are considered, and advice is given on changing from coal to oil firing.

MODERN KILN TYPES.—Nawrath (*Tonind. Ztg.*, **46**, 957, 1922). A brief discussion on (1) annular kilns without roofs; (2) tunnel kilns, and (3) oil-fired annular kilns.

REPORT OF EXPERIMENTS ON PRODUCER-GAS.—K. Morimoto (*J. Jap. Cer. Ass.*, 341, 149; 342, 187; 343, 230, 1921). At the window-glass works of the Asahi Glass Company, hot producer-gas is used to a large extent. The author, who is an expert of the company, noticing that the usual method of sampling gas and its quantitative analysis after it is cooled does not indicate the true nature of the gas, attempted the quantitative analyses of water-vapour and tarry matter in addition to the usual constituents. The various methods hitherto proposed. failed. After many trials. a new apparatus was designed, which has proved to be satisfactory enough for factory use. The apparatus consists of four flasks, an electric fan and a gas-meter. Hot gas is forced through the flasks by the suction fan, which discharges the gas to the gas-meter. The first flask is partly filled with water or heavy oil, into which the end of the tube conveying the hot gas dips; it has also a tin-plate cylinder filled with broken glass or beads at the end of the exit tube. The other three are empty. The second flask has a cylinder similar to the former; the third flask is just like the second, with the exception of the cylinder, which is filled with glass-wool; the last flask has a cylinder containing absorbent cotton and a thermometer. The temperature of the gas at the outlet of the last flask is kept 1°–2°C. higher than that of the room; for this purpose, the flasks are cooled with water or ice. The sample is collected through a tube inserted downward into the downcomer or side walls of the gas-main On setting the fan in motion, about ten cubic feet of gas are taken. Water-vapor and tar, condensing in the cooler are collected, and their amounts are determined. The composition of the gas at the outlet of the gas-meter is determined in the usual way. In calculating the volumes of vapors, it is assumed that tar consists of napthalene and also that water and tar exist in the gaseous state at ordinary temperatures. The experiments at a factory revealed a rather poor nature of the hot gas, and, therefore, many improvements on the producers and their manipulation were undertaken. The following table shows the compositions of the producer-gases before and after improvements:

		CO_2	O_2	C_2H_4	CO	CH_4	H_2	N_2
Before impr.	Cold gas	7·28%	0·56%	0·68%	16·30%	5·20%	13·54%	56·44%
	Hot gas	5·78	0·45	0·54	12·95	4·13	10·76	44·97
After impr.	Cold gas	6·28	0·25	0·27	20·00	8·67	12·20	52·33
	Hot gas	5·72	0·23	0·25	18·20	7·90	11·10	47·66

H_2O	$C_{10}H_8$	B.T.U. per cub. Shaku (net)	Combustion temp.	Temp. of gas
— %	— %	156·20	1578·C.	20°C.
20·20%	0·22%	138·20	1494°	170°
—	—	192·40	1606°	20°
8·70	0·24	189·60	1637°	220°

The calorific power of gas increases as its water content decreases. However, the water-vapor which is introduced by the moisture and combined water of coal is unavoidable, and its amount is about 5·10% at the said factory.

S. KONDO.

PATENTS.

GAS PRODUCER.—T. G. Tulloch and D. J. Smith (*Pat. J.*, 1,740, 1922). No. 177,590, Dec. 23, 1920). A gas producer is described in which the fuel enters through a rotary feeder in such a manner that a constant quantity of fuel can be maintained in the producer.

FURNACE GRATES.—T. O. Wilton and Chemical Engineering and Wilton's Patent Furnace Co., Ltd. (*Pat J.*, 1,743, 1922). No. 178,605, Feb. 4, 1921. A grate is described in which the supply of air and steam through the fire-bars can be regulated.

ELECTRIC FURNACE.—Automatic Telephone Manuf. Co., and P. N. Roseby (*Pat. J.*, 1,744, 1922). No. 178,973, Feb. 5, 1921. The heating element consists of crushed anthracite filling up the spaces between two refractory containers. The current is supplied by carbon electrodes projecting into the anthracite.

CRUCIBLE FURNACE.—F. G. Penny (*Pat. J.*, 1,745, 1922). No. 179,463, July 7, 1921. Describes the arrangement of flues between the main furnace and auxiliary crucible heating furnaces.

STOKING DEVICE FOR BRICK KILNS.—J. Gairing (*Pat. J.*, 1,745, 1922). No. 179,502, Aug. 24, 1921. The apparatus consists of a cylindrical hopper, with two bottoms, between which is the discharging device.

GAS-PRODUCERS.—E. Diepschlag (*Pat. J.*, 1,748, 1922) No. 180,396. Describes a method by which the material is subjected to a preliminary drying by the heat of furnace gases before being passed to the combustion zone.

REGULATING DRAUGHT IN FURNACES.—G. Korngiebel (*Pat. J.*, 176, 1922). No. 179,721, Feb. 26, 1921. Description of a check-draught damper device comprising a casing of larger dimensions than the flue to which it is connected.

FUEL-FEEDING DEVICE.—J. Procter (*Pat. J.*, 1,750, 1922). No. 181,090, Mar. 3, 1921. Relates to a device for top-fired continuous and chamber kilns. A system of rotating screws is provided in and below the hopper.

CRUCIBLE FURNACE.—Stockport Furnaces Ltd., E. Duckworth and A. Mead (*Pat. J.*, 1,751, 1922). No. 181,452. A gas or oil-fired furnace is described in which the heating gases are led off from the crucible chamber through an annular flue, in which is arranged a helical pipe for preheating the air or combustible mixture supplied to the burner.

TUNNEL KILN.—W. G. de Steigner (*Pat. J.*, 1,751, 1922). No. 181,502. The continuous kiln described has a horizontal high-temp. heating zone and downwardly inclined end portions leading to charging and discharging openings. The goods are moved step by step up the inclined portion, then horizontally along the high-temp. section, and finally downwards to the outlet. The kiln is heated by flues around the upper portion. The device for moving the goods consists of a stepped transporter movable horizontally on a support which can be raised and lowered by screwed pillars operated by a reversible electric motor.

FEEDING KILNS.—F. Holzscheiter (*Pat. J.*, 1,751, 1922). No. 181,685. Apr. 12, 1922. Describes apparatus for automatically feeding fuel to kilns from hoppers, singly or in series.

REVERBERATION FURNACE CROWNS.—Wellman Smith Oven Eng. Corp. Ltd. and A. V. Kemp (*Pat. J.*, 1,752, 1922). No. 181,863, Apr. 1, 1921. Relates to a glass-melting or other furnace in the crown of which two passages are formed, the lower for heating the air of combustion, and the upper for the escape of waste gases. Baffles are formed by bricks extending from the arches into the passages, every fourth brick being longer than the others.

GLAZES, ENAMELS.

BLACK GLAZE ON PORCELAIN.—(*Ker. Rund.*, **30**, 269, 1922). A black colour is imparted to a glaze by iron oxide, chromium oxide and cobalt oxide, preferably in an oxidising atmosphere. Under reducing conditions, chrome-green has a tendency to develop, so that the cobalt content has to be increased, at the expense of the chromium. If the glaze has a brown tinge, the cobalt must be again increased. The following mixture may be taken as a basis: 40 parts by weight of Norwegian spar; 13 parts marble; 12 parts washed china clay; 26 parts quartz sand; 3 parts cobalt oxide; 5 parts iron oxide, and 1 part chromium oxide. From 1·5–2 parts of chrome iron ore may be used instead of the oxide, in which case the iron oxide must be reduced proportionally. The following colouring mixtures may also be used in conjunction with an ordinary colourless glaze:

	I	II	III	IV	V	VI
Cobalt Oxide RKO	100	100	100	85	75	30
Manganese Oxide	80	—	28	—	—	—
Iron Oxide	45	60	30	80	225	90
Chromium Oxide	—	—	25	150	280	110
Quartz (ground)	—	240	—	—	—	—

These mixtures are wet-ground very fine, dried, calcined, again ground and thoroughly washed. From 5 to 15% of the dried stain may be added to the colourless glaze, the mixture being then passed to the mill; to I., III. and VI. an equal quantity of quartz must be added to prevent the glaze running in the fire. A beautiful but expensive glaze is obtained by milling with from 10–15% of black uranium oxide.

TYPES OF GLAZES SUITABLE FOR DECORATIVE INLAY PROCESSES.—F. H. Rhead (*J. Amer. Cer. Soc.*, **5**, 259, 1922). The definition given is: A design consisting of a raised, sunken, or flat outline filled in with flat or slightly shaded coats of glaze, preferably coloured matte. The two essentials are a suitable outline, and a type of glaze that will not readily flow over the outline and mix with or run into the surrounding glazes. The method of application is outlined and formulæ are given for a number of glazes in present use. The process is more suited to individual work than to factory production.

RELATION OF COMPOSITION TO THERMAL SHOCK IN STEEL ENAMELS.—B. T. Sweely (*J. Amer. Cer. Soc.*, **5**, 263, 1922). The importance of a good ground coat is emphasised. A white enamel was applied to a No. 1 first coat, having a cubical coeff. of expansion of $318 \times 10\text{-}_7$. The ware was heated to redness and then quenched in water, and began to spall after one or two trials. A No. 2 ground coat, with a coeff. of expansion of $432 \times 10\text{-}_7$, withstood five or six such tests. Further work is in progress.

THE DEGREE TO WHICH DIFFERENT COMPOSITIONS TAKE VAPOUR LUSTRES.—R. T. Watkins (*J. Amer. Cer. Soc.*, **5**, 28, 1922). Glazes having an oxygen ratio of approximately 3 to 1, a medium or low acid content with a B_2O_3 to SiO_2 ratio of approx. 1 to 2·5 and high in lead and low in lime give the best vapour lustre effects.

ENGOBING ROOFING TILES.—(*Kalk Schm.-Ztg.*, **29**, No. 7, 1922) A short, general description of the process.

AN EXPERIMENT IN ELECTRIC SMELTING GLASS ENAMEL.—E. E. Geisinger (*J. Amer. Cer. Soc.*, **5**, 248, 1922). In view of the acute shortage of oil and natural gas (in America), which, it is predicted, will occur not many years hence, it was deemed advisable to find out the fundamental results of enamel smelting by electricity. The glass used for the purpose was a blue-black enamel containing manganese, nickel and cobalt. This was smelted in a combination arc and carbon resistor furnace, in which the heat is transmitted to the bath partly through the trough refractories, but mostly by radiant reflection from the arch. Running on a load of 450 amp., the small testing furnace used registered a temp. of 1,400°C. A 400-gram charge was rendered liquid and quiet within 12 minutes. No reduction of the oxides and no change in the character of the enamel took place.

PAINTING IN UNDERGLAZE COLOURS IN THE BISCUIT.—F. H. Rhead (*J. Amer. Cer. Soc.*, **5**, 376, 1922). A discription is given of the more commonly known underglaze colours together with typical formulae. The various bodies suitable for this purpose are described. The different methods and application and decorative treatment are discussed in connection with both transparent and opaque colours. Comparisons of the technique are made between u.g. painting and oil and water-colour painting. Glazing and firing treatment are also discussed. The paper concludes with some notes on historical types.

RELATION BETWEEN SILICA, ALUMINA AND BASIC OXIDES IN PORCELAIN GLAZES FIRED AT HIGH TEMPERATURES.—Y. Kitamura (*J. Chem. Ind., Japan*, **24**, 89, 1921).

COLD-GLAZED TILES *VERSUS* CERAMIC TILES.—C. Tostmann (*Ber. D.K. Ges.*, **3**, 31, 1922 ; *Ker. Rund.*, **30**, 213, 1922). A report of work carried out at the Seger-Cramer Ceramic Laboratory, Berlin. The samples tested were obtained indirectly through the ordinary trade channels. The earthenware tiles were white, with transparent glaze, and a good "ring." The glaze showed no trace of crazing. The "Cerament" tiles were faced with a smooth cement glaze ; some had a perfectly flat surface, whilst others were wavy. The cerament glaze was much softer than the earthenware glaze ; it could be scratched easily with the finger nail. *Porosity.* This was tested by boiling the dry tiles in water. The average increase in weight for 10 trials was : for earthenware 8·08 per cent., and for cerament tiles 6·71 per cent. The saturated tiles were then used to test their *resistance to frost.* They were subjected 25 times to the action of frost (–15°C.) and after 4 hours exposure were immersed in water at room temperature. The only effect of this treatment was to render the Cerament glaze somewhat matt, so that, in general, both types may be considered as unaffected by frost. *Strength.* The breaking strain for earthenware was found to be 187·3 and for cerament tiles 83·1. *Percussion Test.* The average energy required to break the earthenware tiles was 0·09 m/kg. and the cerament tiles 0·14 m/kg. *Resistance to Acids and Alkalies.* Hydrochloric acid with a Sp. Gr. of 1·12, diluted with water in the following proportions : 1 : 1, 1 : 2, 1 : 5, 1 : 10 and 1 : 50, and soda solutions containing 50, 30, 10 and 2 per cent. of sodium hydroxide were used. After 10 minutes partial immersion in the 1 : 1 and 1 : 2 HCl not only the glaze but also part of the ground on the Cerament tiles was eaten away. With the weaker acids the glaze was either partially destroyed or rendered matt. The effect of the soda solution was much less pronounced, but after 10 minutes in the strong solution the glaze became matt. The earthenware tiles were not affected in any way by similar treatment. *Scouring Test* : On scouring with sand, the greater part, and in some cases the whole of the glaze coating was removed from the Cerament tiles. Similar treatment of earthenware tiles produced practically no effect.

Similar tests have also been carried out by the State Bureau for Testing Materials, Berlin. The results are summarised as follows :—

Property.	Cerament Tile	Earthenware Tile.
Hardness of glaze (Mohs' scale)	2 to 3 (gypsum to calcite)	5 to 6 (apatite to orthoclase)
Resistance to sand-blast, loss of weight in grs.	2·51	1·09
Impermeability to water and oils	Glaze penetrated by water and oils after 24 hrs.	No effect
Porosity (percentage water absorbed)	11·5	8·1
Bending strength in kg/sq. cm.	38	205
Resistance to impact (cm./kg.)	2·64	5·04
Writing effects with— 1. Lead pencil (No. 2) 2. Copying-ink pencil 3. Blue pencil 4. Carbon pencil (arc-lamp) 5. Charcoal pencil 6. White chalk	Legible writing possible with all pencils. The writing with charcoal and chalk could be wiped off with a dry cloth ; that with arc-lamp carbon partially, and the remainder could not be removed.	Writing only possible with copying-ink : this could be wiped off completely with a dry cloth.
Resistance to frost	Alter freezing 11 times, glaze showed traces of peeling. After 25 freezings the glaze in all cases was dull, rough and speckled	One sample after 18 freezings and two others after 21 freezings showed one puncture in the glaze about pin-head size. No further exterior change was noted in any of the samples after 25 freezings
Resistance to Acids— 1. 10% acetic .. 2. 10% HCl 3. 10% HNO_3 4. 10% H_2SO_4	After 14 days glaze softened Glaze destroyed and surface of tile attacked	No effect perceptible after 14 days

These results differ widely in some respects from those of the previous tests. This is explained by the fact that the samples were obtained from different sources, in the first case from Breslau and in the second from South Germany. The later (Berlin) tests, however, place the Cerament tiles in a much more unfavourable light ; their obvious inferiority can be seen at a glance from the above comparative tests.

OBSERVATIONS ON THE FACTORY CONTROL OF FISH-SCALING.—J. S. Grainer (*J. Amer. Cer. Soc.*, **5**, 95, 1922). An analysis of fish-scaling, its causes and prevention based upon observations and experience of practical work are given. Of the various causes which have been advanced the following are selected for discussion : underfiring, character of clay, and type

of furnace. With regard to the first, the writer believes that one of the principal causes of fish-scaling of finished ware is not so much underfiring as overfiring ; and it is important to note that the effects of the latter do not usually become evident until the ware is finished and marketed. Prolonged intense firing destroys or changes either entirely on in part, that property of the clay which tends to regulate the gravity of the enamel until, after burning nothing is left on the ware but the ground frit or glass minus the clay. In enamelling sheet steel, the second of the above factors, namely, that of clay, is the most important. It must be of such a quality that it will still retain its efficiency at the higher temperatures. An even more important requisite is the selection of a clay that will hold the frit in suspension without the excessive use of flotation agents. To test the ability of clays to remain in suspension, the writer placed one pound of each of six well-known clays, regardless of their chemical analysis and prestige, into separate jars and filled up with water. They were then allowed to stand for six days until the clays were thoroughly saturated, after which they were all well stirred and allowed to stand again for one week. It was then noticed that four of the clays settled to the bottom after six hours ; another, a washed clay, though not settling very quickly, gave evidence of being held in suspension by the addition of some chemical agent. The remaining clay settled about half an inch and remained so until the water was entirely evaporated from the surface, a matter of 30 days. A batch of frit was then milled with 10% of this clay and the results were good. With regard to the third cause of fish-scaling, viz. : improper type of furnace, the author expresses a decided preference for the open type for firing enamelled ware. It has a more uniform distribution of heat, which ensures uniform firing of all pieces of ware, thus reducing the risk of over or underfiring. A further advantage is its complete freedom from gas. Another important condition, often overlooked, is that the ground coat is applied too thinly and fired too hard.

MICROSCOPIC STUDY OF GROUND COAT AND COVER COAT ENAMEL REACTIONS.—E. E. Geisinger (*J. Amer. Cer. Soc.*, **5**, 322, 1922). The method of using the microscope in the factory is explained. The degree of susceptibility of enamels to furnace gases is easily classified by cross-section examination. The excess intermingling of ground and cover coats and interaction between ingredients can be determined. The lack of firing range of the two coats is readily noted. The results of overfiring and underfiring are summarised. (13 illustrations).

THE PREPARATION OF A BRILLIANT RED, SILKY GLAZE ON CERAMIC PRODUCTS.—(*Tonind, Ztg.*, **46**, 509, 1912.) German Pat. No. 339, 339. A. Heinecke. A clay, containing finely divided iron oxide in large proportions (10% and more), is mixed with fluxes like wood ash, glass powder, etc., to which is added organic matter such as dextrine, sugar, honey, flour, starch, etc. The objects (fired or unfired) receive a thin coating of this mixture and are then fired in an oven, in which the ware is uncovered, but protected from flying dust and ashes from the grates. The atmosphere must be slightly reducing. The red colour is produced by the reducing action of the carbon from the carbo-hydrates on the iron oxide (at about 400°C.), which is again oxidised by the air during cooling. The brilliance of the glaze is improved if the kiln gases contain water vapour, which prevents the oxidation of the iron during firing. The flux contained in the engobe melts with the clay at high temperatures and forms a glaze-like coating. A temperature of 800°C. should not be exceeded. During the slow cooling process, air is admitted, and stoking is gradually diminished. The iron in the glassy coating is then transferred into brilliant red iron oxide.

ON THE RATIO OF Al_2O_3 AND SiO_2 TO RO IN PORCELAIN GLAZES FIRED AT HIGH TEMPERATURES.—Y. Kitamura (*J. Ind. Chem., Tokio*, **2**, 89, 1921). The work was carried out with a view to study the effect of the variation in the ratio of alumina and silica to bases on the physical properties of hard porcelain glazes and therefrom to find the best ratios for

various temperatures. The range of composition of the glaze was RO : 0·2–2·2 Al_2O_3 : 4–26 SiO_2, where RO is 0·5 KNaO, 0·5 CaO in one series and 0·1 KNaO, 0·9 CaO in the other. Glaze was applied on three different biscuit bodies and burned to Cones 11, 14 and 17. The results are shown in six diagrams. Conclusions : (1) The area within which glazes have marketable lustre and also the area wherein glazes are undermatured but have at least a slight lustre are elliptic ; (2) the lustre-area expands as firing temperature rises ; at the same time, the centre moves in the opposite direction to the origin of axes ; (3) the glaze at the centre of the lustre-area is probably the best one. Thus, the compositions of the best glazes have been calculated :

Table 1. Chemical Formulas of the best Glazes.

Firing temp. (Seger cone)	RO= 0·5KNaO, 0·5CaO	RO= 0·1KNaO, 0·9CaO
11	RO, $0·9Al_2O_3$, $8SiO_2$	RO, $0·7Al_2O_3$, $6·0SiO_2$
14	RO, $1·05Al_2O_3$, $10SiO_2$	RO, $0·95Al_2O_3$, $9·5SiO_2$
17	RO, $1·1Al_2O_3$, $15SiO_2$	RO, $1·1Al_2O_3$, $14·5SiO_2$

(4) extending the result, glazes for intermediate temperatures and other different RO can be calculated. Two examples are given :

Table 2. Calculated Formulas of good Glazes, having 0·1KNaO,0·9CaO as RO.

Firing temp. (Seger cone)	RO	Alumina	Silica	Firing temp. (Seger cone)	RO	Alumina	Silica
11	1	0·70	6·0	15	1	1·01	11·0
12	1	0·80	7·0	16	1	1·06	12·7
13	1	0·88	8·2	17	1	1·10	14·5
14	1	0·95	9·5				

Table 3. Calculated Fgrmulas of good Glazes, having 0·3KNaO, 0·7CaO as RO.

Firing temp.	RO	Alumina	Silica	Firing temp.	RO	Alumina	Silica
11	1	0·80	7·0	15	1	1·05	11·2
12	1	0·87	7·7	16	1	1·08	12·8
13	1	0·94	8·6	17	1	1·10	14·7
14	1	1·00	9·8				

(5) along the major axis of the lustre-area which has been named "Lustre Axis," silica varies proportionally with alumina. The ratio is 0·1 Al_2O_3 : 1·0 SiO_2 except when glazes with 0·1KNaO, 0·9CaO as RO, are burned at Cone 11 ; in this case, the ratio is $0·1Al_2O_3$: 0·8 SiO_2 ; (6) the maximum amounts of alumina and silica in the lustre-area are as follows :

Firing temp. (Seger cone)	RO= 0·5KNaO, 0·5CaO	RO= 0·1KNaO, 0·9CaO
11	$1·3Al_2O_3$, $12SiO_2$	$1·1Al_2O_3$, $9SiO_2$
14	$1·5Al_2O_3$, $15SiO_2$	$1·5Al_2O_3$, $15SiO_2$
17	$1·9Al_2O_3$, $23SiO_2$	$1·9Al_2O_3$, $23SiO_2$

(7) some of the glazes in the lustre-area crazed. Those at or near the centre are safe, while those near the boundary, and, moreover, poor in alumina, have a tendency to craze. S. Kondo.

EFFECT OF VARIATION IN THE COMPOSITION OF GROUND-COAT ENAMEL ON ITS ADHERENCE TO IRON.—S. Mori (*J. Jap. Cer. Ass.*, 343, 233 ; 344, 272,, 1921). Adherence of ground-coat to iron was measured by the impact test, using soft steel sheets, gauge No. 28, measuring 1″×2·5″, as test pieces. An enamel which had proved to be very good in practice was taken as the basis of experiments. Its formula is $0·455Na_2O$, $0·245K_2O$, 0·232CaO, 0·016CoO, 0·955MnO, $0·198Al_2O_3$, $1·490SiO_2$, $0·455B_2O_3$, $0·200F_2$. The content of silica, boric acid, alumina, soda, potash or lime was varied within ranges as follows : $1·266–1·754SiO_2$; $0·455–3·200B_2O_3$; 0·198–0·227

Al_2O_3; 0·426–0·561Na_2O; 0·214–0·306K_2O and 0·136–0·544CaO. Conclusions are: (1) Any increase in silica or boric acid reduces the resistance to chipping; (2) the resistance of enamel to chipping increases with the addition of alumina; (3) adherence of ground-coat is strengthened by the increase of soda, potash or lime up to a certain degree beyond which the effect is reversed. S. KONDO.

MARINE BLUE PIGMENT FOR ENAMELLING.—T. Fukudo (*J. Jap. Cer. Ass.*, 348, 432, 1921). The marine blue colour of enamelled wares is usually produced in Japan by adding copper oxide to raw batches. Since various difficulties have been experienced by enamellers in such a method, its improvement is needful. A German pigment which is added at the mill in the manufacture of marine blue wares was analysed with the result: 32·44% alumina, 4·64% silica, 1·28% magnesia and 0·60% moisture and loss on ignition; and a similar pigment made by heating a batch of 33 cobalt oxide, 24 chromic oxide, 35 alumina, 2 stannic oxide, 1 magnesia and 5 silica to Cone 13 was almost as bright as the imported one. The shade of the pigment can be easily controlled. The effects of the introduction of various substances to the raw batch of pigment upon the clarity of the colour are described; briefly, the addition of stannic oxide, antimony oxide or bone-ash makes the colour clear, while zinc oxide, magnesia, lime and silica tend to make the colour dark or dull. The most economical method is in the utilization of impure alumina which is obtained as a residue in the process of extracting alum from calcined alunite; the alumina used in the experiments had 65·33% alumina, 28·50% silica, 2·46% sulphuric anhydride, 0·67% ferric oxide, 1·25% lime and 1·80% potash. A pigment, made by heating a mixture of 55 impure alumina, 26·1 cobalt oxide and 18·9 chromic oxide to Cone 13 or 15, was as excellent as that imported from Germany. In enamelling, 2% of pigment is added at the mill. S. KONDO.

STUDY OF VEHICLES USED IN ENAMELLING SLIP.—S. Mori (*J. Jap. Cer. Ass.*, 352, 630, 1921). Explanations and discussions on the reason why enamellers use vehicles or stiffening materials, the rôle of clay in enamelling slips, theories of deflocculation of the slip, and the action of vehicles on the slip are given. The effect of various vehicles on the viscosity of an enamelling slip is shown with diagrams. A ground coat enamel with the formula: 0·455 Na_2O, 0·245 K_2O, 0·232 CaO, 0·016 CoO, 0·055 MnO, 0·198 Al_2O_3, 1·49 SiO_2, 0·49 B_2O_3, 0·20 F_2, ground with 5% of washed Gairome (plastic kaolin) and 35% of water, was used for the experiments. The amounts of vehicles required for one litre of slip in making its viscosity most suitable for working were as follows: sodium chloride 4·68 g, barium chloride 0·732 g., aluminium chloride 0·3 g, sodium carbonate 8·4 g, ammonium carbonate 0·9 g, borax 1·98 g, or brine 4 cc. The effect of vehicles diminishes with the lapse of time. Concluding from the results, the author recommends (1) the use of as little water as possible; (2) the removal of water on storing slips; (3) when the use of a vehicle is needed, borax, ammonium carbonate or soda-ash for the ground coat, barium chloride or soda-ash for the cover coat, and aluminium chloride or calcined magnesia for soluble enamels as semi-fused ground coat of cast-iron ware, and (4) the use of stiffened slip within a few hours. S. KONDO.

STUDY OF OPACITY AGENTS FOR ENAMELS.—T. Uchida (*J. Jap. Cer. Ass.*, 357, 189, 1922). Although antimony, which is generally used in Japan for making white enamels, is inexpensive and effective, so far as opacity is concerned, it is much inferior to stannic oxide as to the appearance of enamel and moreover enamels with antimony cannot be exported to some countries where their use is forbidden, and consequently, a study of its substitutes is needed. The results of numerous experiments in which various substances were ground with ten times their weight of frit, made from 26 kg. borax, 59 kg. felspar, 2 kg. nitre and 13 kg. cryolite, applied on sheet iron and fired after drying are as follows: (1) Among the opacifiers on the market and those substances which were considered of high promise, only two specimens

of stannic oxide proved to be excellent; terrar, zirconia, cerium carbonate, and a specimen of stannic oxide were good and antimony oxide, rutile and Izushi clay were moderately good; (2) of various metal oxides obtained by calcining oxalates those of tin, zirconium, antimony and cerium were good and the oxides of lead, zinc and arsenic were moderately good; (3) among several compounds of tin, stannic oxide obtained by calcining the hydroxide at 1,050°C. was excellent and stannic hydroxide was good; (4) antimonic anhydride and antimony tetroxide are better than the trioxide; (5) of various antimonates and stannates, only calcium antimonate proved an excellent opacifier, and zinc stannate was pretty good; (6) the process of manufacturing a compound affects its quality as opacifier, *e.g.*, the stannic oxides which were prepared by igniting metastannic acid, $SnO(OH)_2$, obtained by oxidising metallic tin with nitric acid, at 670°–1,060°C. proved pretty good opacifiers, while good ones were obtained by heating it at 1,100°–1,230°, and finally excellent ones at 1,280°–1,435°; (7) the oxides, silicates and phosphates of aluminium and magnesium deteriorate the lustre of enamels. S. Kondo.

COLOURS, DECORATIVE PROCESSES, ETC.

THE PHOTOGRAPHIC REPRODUCING PROCESS.—C. Fleck (*Sprech.*, **55**, 96, 1922). A general description of the process.

MANGANESE FOR COLOURING BRICKS, ETC.—(*Brick*, **61**, 32, 1922). Manganese may be used to produce better colour in bricks, etc. Light burning and buff bricks can be changed to beautiful French grays, and red burning clays made to produce the popular brown shades. Some remarkable and unusual speckled effects can also be produced.

ON THE UTILIZATION OF SELENIUM.—S. Sugie (*J. Jap. Cer. Ass.*, 341, 152; 342, 193; 343, 226, 1921). The chamber-mud of Japanese factories manufacturing sulphuric acid contains 2–6% of selenium. Flue-dust, anode-slime, slag and other by-products of factories treating sulphur or sulphide ores are also rich in the element, as Japanese ores contain more selenium than those of other countries. (1) *The recovery of selenium from waste products.* Of many well known processes of extracting selenium from chamber-mud, anode-slime, flue-dust, etc., the following two are recommended: (*a*) Selenium is precipitated by means of conc. hydrochloric acid from a solution of sodium thioselenate which has been obtained by heating the material with a solution of sodium sulphite; and (*b*) selenium in the material is oxidised by heating with conc. nitric acid; then sulphuric acid is added to drive off the excess of nitric acid; selenium is precipitated from the solution with sulphurous acid gas, sodium sulphite and hydrochloric acid, or hydrogen sulphide. (2) *Red pigment of selenium for enamel.* Four kinds of fire-red, imported from Germany before the war, had shown the following compositions:

	No. 1.	No. 2.	No. 3.	No. 4.
Cadmium	28·2%	24·3%	17·3%	39·1%
Alumina	36·4%	53·8%	49·4%	45·5%
Sulphur and selenium	35·4%	11·9%	33·3%	15·4%

Starting from this result, many experiments were done, and a new method of manufacturing pigments which are as satisfactory as German fire-red has been invented. The method is as follows: a mixture of cadmium sulphide and selenium is heated in a porcelain crucible gradually up to about 500°–700°C. and the temperature is maintained till the content becomes dark brown and the fuming of violet selenium is almost over, stirring the contents at times; it is then cooled, still stirring the contents; batch-compositions were:

	D	E	G	F	H	A	B	C
Cadmium sulphide	82%	85%	85·5%	86%	86·5%	87%	89%	90%
Selenium ..	18%	15%	14·5%	14%	13·5%	13%	11%	10%

The colour of the pigments changes continuously from blackish red of D to yellowish red of C. Black shade is also added by heating to higher temperatures or heating up rapidly and continuing it longer. For enamelling, a

coating of transparent frit with 3–5% of the pigment is applied and fired on the white coating Of several frits used for the purpose, one composed of 35 sand, 30 borax, 15 fluorspar, 6 cryolite, 14 sodium carbonate and 2 nitre gave the best results. (3) *Use of selenium as pink colorant and decolorizer of glass.* A historical survey on the subject is given. Concluding from many experiments, the author says : (1) selenium does not colour soda-lime glasses pink, but tends to give them a yellowish brown ; (2) selenium, regardless of its sources, colours potash-lime glasses pink ; (3) the amount of selenium required for decoloration is about 1·5% of the amounts of ferric oxide in batches ; (4) $CaSeO_3$, $BaSeO_3$ and $PbSeO_3$ are the most effective sources of selenium ; (5) the action of selenium is hindered by the presence of oxidising substances, *e.g.*, red lead ; (6) the required amount of arsenious oxide is about three times that of selenium. In either case, it is impossible to get a dark red glass by selenium, as it is volatile at high temperatures. In general, selenites of alkalies or ammonium are very hygroscopic, therefore they are inconvenient in use. S. KONDO.

PATENTS.

PROCESS OF DECORATING POTTERY.—Kosaburo Kano (*Jap. Pat.* No. 38,872, June 11, 1921). A design of lettering is printed on paper with a paste composed of glaze 8, orchid-root 1, syrup, sugar or rice-jelly 1 and the proper amount of warm water. Then it is transferred on biscuited ware ; a hard fire colour is painted on the design or lettering and its neighbourhood. The print repels the colour and remains uncoloured. The glaze is then applied to the whole surface and the ware is fired at a high temperature. S. KONDO.

PROCESS OF MANUFACTURING LIQUID GOLD.—Jiro Ishikawa (*Jap.* Pat. No. 40,632, November 14, 1921). Sulphur-balsam is added to a solution of gold chloride and the mixture is heated on a water-bath. Sulphur-resin-gold, thus prepared, is washed and heated to evaporate water. The resinates of aluminium, uranium and bismuth are then added. The product is dissolved in a mixture of lavender and rosemary oils. S. KONDO.

PLANT AND MACHINERY, ETC.

MECHANICAL KILN STOKER AND GRATE.—(*Brick*, **60**, 913, 1922) The apparatus consists of a small ¼ h.p. electric motor operating a friction clutch, which rotates a heart-shaped cam, on the edges of which rides a cam-follower. The follower is supported between two upright straps, connected to the driving rod at their upper ends and hinged at their lower ends. The driving rods extend all the way round the kiln, and a slide at each fire box is connected to the driving rods by a series of simple levers. The slides are fed with fuel from hoppers located directly above them. The cam rotates slowly with the cam-follower riding on its edge, pressed against it by a compression spring. When the depression in the cam is presented to the follower, the force of the spring is permitted to act on the vertical straps throwing them to the right. They in turn carry the driving rods to the right and each slide discharges its fuel on to the fire. By turning a set-screw, any desired frequency of stoking may be obtained. The hoppers hold about 50 lb. of fuel, and all that is necessary is to fill them as required. The size of the slides or scoops may be altered to suit different conditions. The grate is straight, but slants about 9″ in 42 and extends to the bag wall of the fire box. At the rear it rests on a cross-bar. In the front it is held in position by a series of levers. The grate itself is in two sections, a coking plate and the grate proper, hinged together. By a simple movement of levers, the grate is dumped downward and outward, opening a space of about 8″ between the rear end of the grate and the bag wall, over which the ashes and clinker may be pushed to the bottom of the box and removed. There are two illustrations.

INDUSTRIAL APPLICATIONS OF THE COLLOID MILL.—S. P. Schotz (*Chem. Age*, **6**, 790, 1922).

STEEL BELT CONVEYORS FOR NORMAL, ABRASIVE AND PLASTIC MATERIALS.—(*Brick Pot. Tr. J.*, **30**, 133, 1922). An illustrated account of a conveyor recently introduced by Steel Belt Conveyors, Ltd., of Birmingham. The band is of the finest quality steel of the Swedish "Sandvik" type.

THE ENGINE.—(*Brit. Claywr.*, **31**, 75, 1922). Some practical hints on the proper maintenance of the works' engine.

AUTOMATIC CONVEYORS.—S. Higgins (*Brit. Claywr.*, **31**, 86, 1922). A brief account with 5 illustrations, of a few conveyors and elevators seen or used by the author.

THE AMERICAN LIME AND STONE CO'S. PLANT.—C. S. Darling (*Rock Prod.*, **25**, No. 12, 59, 1922). This is described as a "plant ahead of its time." It contains a rotary kiln for dry or semi-wet burning, with a 175-ft. flame. The article is well illustrated.

THE STEAM BOILER.—(*Brit. Claywr.*, **31**, 109, 1922). Some practical hints.

FACTS ABOUT CRUSHING ROLLS.—(*Brit. Claywr.*, **31**, No. 360, 7, 1922).

A MODERN SANITARY-WARE PLANT.—(*Brick*, **60**, 776, 1922). A short account—well illustrated—of the new plant of the Mutual Potteries, which consists of a group of 4 buildings, each over 300 ft. long.

THE STANDARDIZATION OF FILTER PRESSES.—(*J. Soc. Chem. Ind.*, **41**, 210R, 1922). Report of a joint sub-committee of the Association of British Chemical Manufacturers and the British Chemical Plant Manufacturers' Association, compiled on the replies to a questionnaire. Some desire was shown for a 48-inch plate, and the Committee puts forward in this Report some suggestions concerning these.

METHODS OF PREPARING CLAY.—(*Tonind. Ztg.*, **46**, 650, 1922). A description of 3 up-to-date machines is given. (3 illustrations).

THE ELECTRICAL OPERATION OF THE RIVER ROCK GRAVEL COMPANY.—A. V. Thompson (*Cement Eng. News*, **34**, No. 5, 19, 1922). A description of a plant in Central California, on which electricity is used exclusively for all operations.

Patents.

JIGGER HEADS.—W. G. Lawson (*Pat. J.*, 1,744, 1922). No. 178,927, Jan. 24, 1921. The jigger head is provided with vertical slots, through which radial arms, attached to the false bottom, project, and are vertically removable to raise the false bottom.

ROLLER MILLS.—A. G. Simms (*Pat. J.*, 1,744, 1922). No. 179,090, June 24, 1921. Relates to machines of the type in which the rollers are mounted so that they can be withdrawn as a whole by removing the shafts on which they are mounted.

CRUSHING MILL.—H. Aldehoff (*Pat. J.*, 1,745, 1922). No. 179,171, Apr. 26, 1922. The ground material is discharged from the mill on to a sieve, the fines passing through into a funnel to a bag-filling apparatus, while the coarse material passes by a channel to a trough, from which it is returned by an elevator and a shoot to the feed hopper. The sieve is fitted so as to be agitated by the mill.

BRICK-MAKING MACHINE.—Ateliers de Construction et Fonderies A. Rasquin et F. L. Joovis (*Pat. J.*, 1,745, 1922). No. 179,541, May 2, 1922. In the machine the material is extruded from a vat, having a false bottom, through a delivery outlet, comprising a conical frame connected to the vat by pivoted rods and keys.

BRICK PRESS.—Whittaker & Co., Ltd. & N. Whittaker (*Pat. J.*, 1,737, 1922). No. 176,425, Oct. 23, 1920. Relates to feed-mechanism.

BRICK MACHINE.—Whittaker & Co., Ltd. & N. Whittaker (*Pat. J.*, 1,737, 1922). No. 176,426, Oct. 23, 1920.

POTTERS' LATHES.—S. Green (*Pat. J.*, 1,738, 1922). No. 176,974, Jan. 24, 1921. Describes driving and reversing mechanism for potters' lathes, comprising a hollow speed cone mounted on a sleeve on a shaft or spindle.

FEEDING DEVICE FOR ROLLER MILLS.—P. Turner (*Pat. J.*, 1,739, 1922). No. 177,381, Mar. 8, 1921.

TUBE MILLS, ROTARY FURNACES, ETC.—E. G. Stone (*Pat. J.*, 1,741 1922). No. 177,790, Mar. 29, 1922. Description of a machine in which the rotary cylinders are supported on rigid bearings and are buoyed up during rotation by water contained in jackets surrounding the cylinders.

BRICK PRESSES.—T. C. Fawcett, Ltd. & D. L. Fawcett (*Pat. J.*, 1,742, 1922). No. 178,237, Jan. 31, 1921. Relates to a system of liners of relatively hard metal with inserts of softer metal capable of being drilled.

PUG-MILLS.—Fawcett, Ltd., J. W. Bottomley & D. L. Fawcett.—(*Pat. J.*, 1,747, 1922). No. 180,035. Two overlapping and tapered worms rotating in the same direction, have their axes inclined to one another. The worms are supported at the feed end only, and the centre of the mouthpiece aligns with the centre line of the overlapping part of the worms.

BRICK MACHINES.—Fawcett, Ltd., & D. L. Fawcett (*Pat. J.*, 1,747, 1922). No. 180,122. Relates to cylinder brick machines with open-ended pockets.

MOULDING MACHINES.—K. Sprenger (*Pat. J.*, 1,748, 1922). No. 180,416. Relates to machines with separate press and moulding chambers. The patent provides for delivering the material under pressure to the most advantageous position for distribution in the mould.

MOULDING CLAY.—L. B. Tickle & H. J. W. Barnes (*Pat. J.*, 1 748, 1922). No. 180,477. Describes a machine of the hopper-and-plunger type, particularly adapted for moulding small articles like electric insulators, switch boxes, lamp holders, etc.

ENAMELLING MACHINE.—Br. Thomson-Houston Co. Ltd. (*Pat. J.*, 1,752, 1922). No. 181,989, July 5, 1921. Describes a centrifugal coating machine.

III.—FINISHED PRODUCTS: TESTING, ETC.

SCUM ON BELGIAN BRICKS.—(*Tonind. Ztg.*, **46**, 632, 1922). A yellow or reddish scum, at present very prevalent on bricks imported into Holland from Belgium, was found by C. Visser (Delft) to have the following average composition : 92·71% $MgSO_4.7H_2O$; 0·95% $CaSO_4.2H_2O$; 4·17% insoluble in water (calcium carbonate and brick powder) ; 1·12% alkali sulphates ; 1·05% water. There was also distinct evidence of scaling in the brick surface underneath the scum. The trouble was considered to be due undoubtedly to the magnesium sulphate. A brick core contained 2·38% $MgSO_4.7H_2O$ and 2·46 $CaSO_4.2H_2O$. An excessive SO_3-content was characteristic of Belgian bricks. A Belgian clay from the Rupel district contained 0·07%, sol. MgO, 0·04% Na_2O and 0·06% SO_3, whilst a brick from the same district contained 0·02% MgO, 0·06% Na_2O and 0·38% SO_3, thus pointing to the influence of sulphurous fuel. The question as to whether the scumming is due to the clay itself or the firing process is now under investigation by Prof. Visser.

A NEW HOLLOW BRICK.—(*Tonind. Ztg.*, **46**, 855, 1922). An account of German Pat. No. 770,966, by Fr. Püchel. The bricks measure $28 \times 13{\cdot}5 \times 8$ cm. and the perforations are elliptical in form, giving the bricks a comparatively high resistance to pressure.

A SIMPLE CONTROL POROSIMETER.—G. A. Bole and F. G. Jackson (*Brick*, **61**, 314, 1922). The porosimeter is based on the air displacement principle put forward by Washburn and Bunting (*J. Amer. Cer. Soc.*, **5**, 112, 1922) The pore volume is measured by allowing the gas which fills the pores to expand into a measured volume and measuring the accompanying fall in pressure The apparatus, which is simple and easily made, comprises : (*a*) an inverted bell jar within which is a sheet-iron container just large enough to hold a paving brick. The jar has an air-tight glass cover The free space around the container is completely filled with boiling paraffin which is allowed to cool under vacuum, care being taken to remove all occluded air ; (*b*) a two-litre reagent bottle ; (*e*) an oil trap ; (*a* and *b*, and *b* and *e* are connected with thick glass tubing, fitted with well-fitting glass stop-cocks) ; *e* is connected to *c*, a vacuum pump ; (*d*) a flat mercury reservoir ; (*f*) a sloping column manometer (1 m. of length= 150 mm. horizontal rise). *b* is also connected with the manometer. Air is first pumped out of *b* until the mercury has risen to about 2,800 mm. on the scale. The stop-cock between *a* and *b* is then opened, allowing the air in *a* to expand into *b*, and the manometer is again read. The method of calculating the results is explained.

REFRACTORIES FOR COKE-OVEN CONSTRUCTION.—W. J. Rees (*Brit. Claywr.*, **31**, 130, 1922). The use of pure silica bricks is advocated. The presence of salt in coals causes rapid corrosion both of fireclay and of semi-silica (80–90% SiO_2) bricks. R. conducted a series of experiments, in which silica, siliceous fireclay, semi-silica, and fireclay bricks were exposed to the action of salt vapour (both with and without water vapour) at temperatures from 800 to 1,200°C. The attack was much greater on bricks containing clay than on silica bricks, particularly between 900 and 1,100°C. Silica bricks for use in coke oven construction should be made of properly graded material, so as to secure a minimum porosity, and should be adequately burned so that only a small proportion of unconverted quartz remains in the finished brick. With silica bricks of approximately the same composition (*i.e.*, 1·8 to 2·5% CaO and 94 to 97% SiO_2), a specific gravity determination made on the powdered brick forms a sufficient guide to the extent of conversion of quartz. Summarizing, the advantages of silica bricks are : (1) resistance to corrosion where salty coals are coked ; (2) increased output due to higher thermal conductivity ; (3) greater durability (mechanical strength), especially under high temp. conditions.

TESTING MATERIALS.—(*Mitt. Materialprüfungsamt*, Berlin, **39**, 202, 1912). A report of the Building Materials Section of the Berlin Bureau for Testing Materials, covering the work done in 1921.

COMPARATIVE TESTS OF AMERICAN AND FOREIGN TABLEWARE.—H. H. Sortwell (*J. Amer. Cer. Soc.*, **5**, 276, 1922). The American Bureau of Standards has carried out a number of comparative tests on a large variety of wares, including representative French, German, English and Japanese products, which ordinarily are imported in large quantities. The data published refer to absorption, porosity, bulk specific gravity, resistance to crazing and sudden temperature changes, resistance to impact, resistance to chipping, and resistance to alkaline solutions. The results are collected in Table I. *Absorption, Porosity and Bulk Specific Gravity.* For the practical comparative tests, about 40 grs. of pieces, approximately one inch square, broken from the centres of plates, were dried at 110°C., weighed, boiled in water for one hour, and allowed to remain in water 18 hours after boiling. They were then weighed suspended in water, and finally wiped with a damp cloth and weighed again. The formulæ used in the computations were : (1) Per cent. absorption by weight $= 100 \times \frac{W-D}{D}$; (2) Per cent. apparent porosity by volume $= 100 \times \frac{W-D}{W-S}$; (3) Bulk specific gravity $= \frac{D}{W-D}$, in which D is the dry weight, S the weight of the saturated pieces, suspended in water, and W the weight of the pieces saturated with water.

TABLE 1.

No.	TYPE OF WARE	Average per cent Abs.	Average per cent Por.	Average Bulk Sp. Gr.	Average Impact Energy ft. lbs.	Average Thickness at Break in Inches	Average Impact Energy to chip ft. lbs.
1	Hotel ware, rolled edge	0·0	0·0	2·36	0·200	0·213	0·400
2	do. do.	·0	·0	2·30	·250	·215	·250
3	do. do.	·0	·0	2·30	·300	·212	·250
4	do. do.	·2	·4	2·40	·300	·194	·275
5	Light Hotel ware, plain edge	·0	·0	2·40	·175	·190	·125
6	Hotel ware, rolled edge	·6	1·4	2·38	·275	·234	·350
7	do. do.	·8	1·9	2·38	·275	·187	·275
8	do. do.	·3	·7	2·38	·200	·222	·275
8a	Heavy hotel ware, plain edge	·3	·7	2·38	·253	·259	·325
9	Hotel ware, rolled edge	·0	·0	2·30	·150	·172	·125
10	do. do.	1·4	3·2	2·33	·400	·203	·225
11	do. do.	4·8	10·5	2·16	·225	·246	·125
12	do. do.	7·9	16·2	2·05	·250	·156	·100
13	Heavy hotel ware, plain edge	9·8	19·9	2·33	·125	·238	·200
14	English hotel ware, rolled edge	3·4	7·7	2·33	·150	·215	·300
15	do. do.	6·0	13·5	2·23	·150	·193	·225
16	do. do.	2·7	6·1	2·23	·125	·190	·200
17	do. do.	5·1	10·8	2·13	·175	·157	·150
18	French hotel ware, plain edge	·0	·0	2·18	·100	·194	·100
19	German hotel ware, rolled edge	·0	·0	2·33	·125	·168	·375
20	do. do.	·0	·0	2·35	·100	·214	.125
21	Household ware, semi-vitreous	8·5	17·1	2·01	·175	·155	
22	do. do.	10·2	20·3	1·98	·175	·184	
23	do. do.	7·4	15·2	2·05	·175	·162	
24	do. do.	8·4	17·1	2·04	·200	·145	
25	do. do.	7·9	16·2	2·06	·200	·162	
26	do. do.	9·6	19·2	1·99	·200	·182	
27	do. do.	8·7	17·5	2·03	·175	·154	
28	do. do.	8·2	17·2	2·10	·175	.159	
29	Household ware, vitreous	·0	·0	2·32	·225	·160	
30	Japanese household ware	·0	·0	2·23	·100	·180	
31	do. do.	·0	·0	2·29	·100	·188	
32	French household ware	·0	·0	2·20	·075	·122	
33	do. do.	·0	·0	2·25	·150	·134	
34	German household ware	·0	·0	2·38	·150	·150	
35	do. do.	·0	·3	2·35	·150	·110	

The results given in Table I. are averages for six plates of each make. Two of the American hotel wares were earthenware, with absorption figures of 7·9 and 9·8 per cent. The English wares were not vitrified, the absorption ranging from 2·7 to 6·0 per cent. while the French and German hotel wares were completely vitrified to a glassy structure. The American earthenware commonly called semi-porcelain or semi-vitreous china, varied in absorption from 7·4 to 10·2 per cent.

Crazing Test. After considering several methods previously used by different workers, it was decided that a number of immersions, at a temperature of about 180°C. would give reliable indication of freedom from crazing in use. Before quenching, the plates were heated in an electric furnace from 20 min. to half an hour to ensure uniform temperature conditions as indicated by a thermometer at different places on the specimens. After ten immersions at 175°, the plates were quenched five times at 200°, five times at 225° and five times at 250°C. This treatment obviously gives a measure of the ability of the plates to withstand sudden temperature changes also; most of the vitreous bodies would not stand the sudden changes and cracking of the plates resulted. This property is important, in view of the repeated scalding to which the plates are subjected in the dishwashing machines. Of the six brands of American hotel ware tested, none crazed at 175°; one crazed on the third immersion at 200°, and one on the second at 225°. One brand cracked at 225° and three at 250°. Two wares, No. 1 vitreous and No. 11 semi-vitreous stood the entire treatment without crazing or cracking. The four brands of English hotel ware crazed easily, one on the second quenching at 175°, two on the third, and one on the seventh; consequently, they would not pass specifications based on this test. A crazing developed in the French and German hotel wares tested, but they showed a greater tendency to rupture from sudden changes in temperature. Of the eight American semi-vitreous household wares, only one failed to stand treatment at 175·C. Two semi-porcelains withstood the entire treatment without failure, one of which, No. 28, was made wholly of American raw materials. No crazing appeared in the foreign chinas for household use, but all were susceptable to sudden temperature variations. One of the Japanese wares cracked on the seventh quenching at 175°, and the other on the fourth at 200°. One of the best-known brands of French china was completely shattered on the first immersion at 175°, while the other French ware cracked on the tenth quenchimg. One of the German products cracked on the fifth treatment at 175° and the other at the fourth at 200°. The effect of the structure of the bodies on their ability to withstand sudden temp. changes was clearly evident, the porous wares withstanding quenching at 250° without failure, the vitrified, but still granular, American bodies not failing until 225° or 250°, and the glassy French, German and Japanese products on treatment at 175° and 200°.

Impact Test. For this test, a modification of the Staley-Hromatko apparatus was used, consisting of a steel disc, weighing 6 ounces, suspended on a 2-ft. rigid wire arm. A ninety-degree segment, calibrated in divisions of 0.025 foot pound energy of impact, was placed in position at the other end of the arm. In testing the plates were held with the bottom resting lightly but solidly against the seat and they were struck in the centre. The results are given in Table I. The strongest ware tested was No. 10, which had an absorption of 1·4% and required a blow of 0·400 ft. pound to cause fracture. The 13 American brands of hotel ware required, with two exceptions an average blow of 0·200 to 0·400 ft. lb. The four English varieties were not so strong, while the French and German wares were brittle. From the point of view of this test, the results show that the American wares are much superior to the imported brands. The same applied to the household wares. The effect of the structure of the body is again well brought out. The comparatively granular American vitrified wares had a relatively high resistance to impact, the glassy, impervious imported wares being correspondingly brittle.

Chipping Test. This was essentially an impact test and the same apparatus was used, except that the disc was replaced by a six-ounce rectangular block of hardened steel, the striking edge being rounded off. The plates were seated horizontally on a stationary iron slab on which were bolted two steel bars forming an angle of 90 degrees ; they were struck at a point on the edge so that the blow was absorbed equally at the two points of contact of the edge with the bars. Only hotel wares were submitted to this test. The results given in Table I. show that there is no direct relationship between them and the impact figures. The shape of the edge and the angle of inclination of the iron would appear to be important factors. Plates of the same or similar body properties, but of different edge design were found to give widely different results in this test.

Resistance to Alkaline Solutions. In order to determine the effect of such solutions as are used in dishwashing machines, plates of each make were boiled for six hours in a half-normal ($3\frac{1}{2}$ oz. per gallon) solution of sodium carbonate, and six hours in a 4*N* (27 oz. per gallon) solution. No effect of this treatment was noticed on any of the plates. Certain plates were then scratched with a diamond point so that the solution could come into contact with the glaze beneath the glossy surface. They were then boiled for 25 hours in the half-normal solution, but on careful examination were again found to be unaffected.

BERYL AS A CONSTITUENT IN HIGH-TENSION INSULATOR PORCELAIN.—R. Twells, Jr. (*J. Amer. Cer. Soc.*, **5**, 228, 1922). The work of previous investigators is briefly discussed. In two series of experiments, the writer studied the effect of replacing flint and felspar, weight for weight, with beryl, the clay content being maintained constant. Bars and discs were fired to cone $8\frac{3}{4}$, 10, or to $10\frac{3}{4}$ and tested for shrinkage, transverse strength, impact strength, heat resistance, absorption of moisture, and dye penetration. The best bodies for use were found to be those having the following range of composition : Clay 48·54%, felspar 13·3–23·98%, flint 0–5·83%, beryl 21·65–37·63%. The averages of ten trials for dielectric strength were : for a standard body (48·54% clay, 33·98% felspar, 17·48 flint) 150 volts per mil., and for the best all round beryl body 175 volts per mil. The beryl body has less firing shrinkage, is 22·5% stronger in transverse strength, 44% more resistant to impact, 17% stronger in dielectric strength, and over 145% more resistant to temperature changes.

TESTING PORCELAIN.—R. Rieke and M. Gary (*Ber. D.K. Ges.*, **3, 5**, 1922). A report on the work of Committee 18 (Standardization of Porcelain Testing Methods) of the German Association for Testing Materials. Samples supplied by 8 different makers were tested. *Tensile Strength* was tested in a modification of a cement testing machine. The test pieces were made in the form of a figure 8, the upper and lower portions being gripped at right angles between two powerful claws. *Localised Crushing Strength* was determined by a modification of the Brinell test, pressure being exerded at the centre of porcelain discs (10 cm. in diam. and about 1 cm. thick) by two steel balls of $1\frac{1}{4}''$ diam. The Frühling-Michaelis apparatus was employed to determine the *bending stress*, rods of 16 mm. diam. being supported on steel knife-edges 10 cm. apart. The load was applied at the rate of about 1 kg. per sec. The *resistance to impact* was tested in the Schopper pendulum impact tester, built on the Charpy principle, in which cylindrical test rods (16 mm. diam.) are supported horizontally. The energy required to break the rods is measured in the usual way by means of a pointer. *Results* of the four tests on the 8 different materials are tabulated fully. In the following table, the columns headed M give the mean values for a number of experiments ; the figures in columns headed $\pm\Delta$m. represent the average percentage deviation from the mean values. These latter figures vouch for the reliability of a particular test ; the more reliable the test, the lower the value of $\pm\Delta$m.

Material	Tensile Strength M (kg./cm.²)	±Δ m.	Loc. Crushing Strength M (kg.)	±Δ m.	Bending Stress M (kg.)	±Δ m.	Impact Test M (cm. kg./cm.²)	±Δ m.
A.	204	7·1	674	9·4	656	5·4	1·75	3·4
B.	161	8·2	731	3·5	588	5·0	1·77	1·2
C.	231	4·5	960	16·7	670	4·0	1·80	1·0
D.	199	10·8	595	9·6	696	4·6	1·83	0·8
E.	239	9·6	1384	8·2	777	4·0	1·95	2·4
F.	320	9·1	1376	9·8	855	6·0	1·99	3·6
G.	250	11·5	986	11·9	686	2·2	1·88	1·8
H.	265	7·6	1015	5·9	690	1·0	1·88	1·8

The above table shows (columns $\pm\Delta$m.) that, of the four tests, the most accurate is the impact test ; whilst the tensile strength and crushing strength tests may be considered approximately equal in this respect. Averaging the results in the order of increasing tensile strength, and representing the values for material B by 100, we get the following comparative figures :—

Material	Tensile Strength	Loc. Crush. Strength	Bending Stress	Impact
B.	100	100	100	100
D.	124	131	119	103
A.	127	92	112	99
C.	143	131	114	102
E.	148	189	132	110
G.	155	135	117	106
H.	165	139	117	106
F.	199	188	145	112

As regards tensile strength and crushing strength, the variations between the worst and the best bodies amounted to 89 and 99 per cent., whilst for the bending stress and impact resistance the corresponding figures fall to 45 and 12 per cent. Compared with material B= 100, the values for impact, bending and crushing strengths are in the relationship of approximately 1 to 1·1: 1·1 to 1·5 : 1·3 to 1·9 : 1·3 to 2·0. To make full use of the figures obtained, a knowledge of the composition and methods of preparing the bodies and of the raw materials used would be required, but this, for obvious reasons, was not readily obtainable. The *porosity* of the 8 specimens was determined in the usual way, under pressure, using a solution of fuchsine in methylalcohol. In no case was any colour absorbed by the porcelain. The actual pore spaces were calculated from the difference between the true and apparent specific gravity. The true sp. gr. was determined in small pycnometers of 5 cc. capacity, and the apparent sp. gr. on larger pieces weighing 15 to 20 grs.

Porcelain	True Sp. Gr.	Apparent Sp. Gr.	Difference	Pore Space
A.	2·464	2·269	0·195	7·9%
B.	2·459	2·299	0·160	6·5%
C.	2·473	2·345	0·128	5·2%
D.	2·440	2·341	0·099	4·1%
E.	2·446	2·310	0·136	5·6%
F.	2·424	2·317	0·107	4·4%
G.	2·449	2·298	0·151	6·2%
H.	2·495	2·376	0·49	4·8%

No obvious relationship appears to exist between the value of pore space and the various test values, with the possible exception of the impact figures, which, in general, are lowest for those bodies having the greatest pore space and *vice versa*. The figures for pore space in above table were confirmed by microscopical examination (thin section) of the materials :

It is concluded that the best porcelain is one which contains no free quartz, *i.e.*, one in which the quartz, as a result of very fine grinding, high firing temperature and a long firing period, is completely dissolved in the glassy matrix. Arranged according to this plan, beginning with the material containing the least amount of undissolved quartz, the porcelains examined give the following sequence : F–E–D–G–A–C–H–B, whilst the order of de-

Body	Average Number of quartz grains in optical fields (0·29 sq. mm.	Size of largest grains in mm.	Size of majority of grains in mm.	Number of air spaces	Sillimanite formation
A.	18	0·05–0·07	0·01–0·03	appr. 150	Considerable ; well developed in parts.
B.	40	0·08–0·12	0·02–0·04	10	Abundant ; well developed needles
C.	30	0·07–0·08	0·02–0·04	10	Not very clear
D.	50	0·05–0·07	0·005–0·025	15	Very fine ; little development
E.	30	0·04–0·05	0·005–0·02	20	Cloudy clusters
F.	10	0·025	0·005–0·01	15	Abundant ; in cloudy clusters
G.	45	0·05–0·07	0·05–0·03	15	Fairly considerable
H.	60	0·07–0·08	0·02–0·05	8	Recognisable in places

creasing strength would be approximately as follows : F–E–H–G–D–C–A–B. A certain similarity between these two sequences cannot be denied.

THE HEAT INSULATING PROPERTIES OF BUILDING MATERIALS.—H. Burchartz (*Tonind. Ztg.*, **46**, 713, 1922). The high insulating properties of sand lime bricks is due to their density and quartz content. In general, they are not inferior in this respect to ordinary bricks.

A NEW APPARATUS FOR DETERMINING THE SOFTENING TEMPERATURE OF REFRACTORIES UNDER LOAD.—W. Steger (*Ber. D.K. Ges.* **3**, 1, 1922). The apparatus consists of a framework of T-iron, and can be moved up to the electric furnace on two rollers. A 100–120-volt electric carbon resistor furnace is used, which requires about 6 kw. for a temp. of approx. 1,600°. The press rods are made of hard electrode carbon, or carborundum. The movement of the main lever can be magnified about 20 times, and an arrangement is made for automatic recording. To determine the temp. of the test piece accurately, the upper press rod is made with a central hole of 1·6 cm. diam., through which the temp. of the *centre* of the upper surface of the test-piece can be measured by means of a Holborn-Kurlbaum pyrometer. For temperatures higher than 1,400°, when furnace fumes interfere with optical measurements, the central bore is fitted with a highly refractory tube closed at the lower end. The temp. of the inner surface of the bottom of this tube can then be measured either optically, or (better) by means of a thermo-element, the latter method permitting automatic registration of the rise in temp.

ON TESTING THE TENSILE AND CRUSHING STRENGTH OF EARTHENWARE.—(*Ker. Rund.*, **30**, 131, 1922). The Director of the Dutch Ceramic School at Gouda, F. Regout, carried out a series of tests on the tensile and crushing strengths of earthenware, with the object of determining the causes of the erratic behaviour of the different kinds of earthenware with regard to strength and stability. His report appears in the Dutch journal *Klei* (No. 17, 1921). In order to discover the effect of the raw materials, body composition, and the firing temperature on the strength of the ware, a number of body mixtures were prepared and fired to different temperatures. The composition of these bodies, together with the corresponding rational analyses are given below :—

Body	Composition	Rat. Analysis	Body	Composition	Rat. Analysis
C.	24% lean clay 33% china ,, 38% quartz 5% felspar	41% clay substance 54% quartz 5% felspar	H.	22% Meissen clay 45% china ,, 22% quartz 10% chalk	48% clay substance 42% quartz 10% chalk
D.	23% lean clay 32% china ,, 37% quartz 5% felspar 3% chalk	40% clay substance 52% quartz 5% felspar 3% chalk	K.	24% Meissen clay 48% china ,, 23% quartz 5% felspar	51·5% clay sub. 43·5% quartz 5·0% felspar
E.	25% fat clay 50% china ,, 20% quartz 5% felspar	62% clay substance 33% quartz 5% felspar	L.	23% Meissen clay 46% china ,, 23% quartz 5% felspar 3% chalk	50% clay substance. 42% quartz 5% felspar 3% chalk

The samples were fired to Cones 01a, 4a, and 8, *i.e.*, to 1,080°, 1,160° and 1,250°C. and the following figures were obtained for the tensile and crushing strengths.

Body	Crushing Strength (kg./sq. cm.)			Breaking Strain (kg./sq. cm.)		
	Cones			Cones		
	01a	4a	8	01a	4a	8
C. ..	29	31	59	68	86	162
D. ..	29	33	61	78	91	157
E. ..	43	43	80	96	135	185
H. ..	38	41	44	77	87	108
K. ..	32	33	72	66	87	174
L. ..	24	29	76	72	78	162

From these results it would appear that the clay substance content exerts the greatest influence upon the strength of the ware, since the body with 62% clay substance gives the highest figures both for crushing and breaking strength. But this percentage is too high for earthenware; the colour is somewhat yellow, due to the presence of iron oxide in the fat clay. With an equal percentage of clay substance present, those bodies made up with fat clay are the strongest. Body H containing 10% chalk, when fired at the low temperature of Cones 01a and 4a, is not inferior in strength to the felspathic bodies. At temperatures beyond Cone 4a, the lime body improves little, whilst the felspathic bodies, owing to their greater refractoriness, only become dense and solid at higher temperatures. The effect of firing to higher temperatures is shown in the following table, in which the strength at Cone 01a is taken as units:

Body	Crushing Strength (kg./sq. cm.)			Breaking Strain (kg./sq. cm.)		
	01a	4a	8	01a	4a	8
C. ..	1	1·7	2·03	1	1·26	2·38
D ..	1	1·15	2·14	1	1·17	2·02
E ..	1	1·00	1·86	1	1·40	1·93
H ..	1	1·06	1·14	1	1·12	1·37
K ..	1	1·04	2·25	1	1·32	2·64
L ..	1	1·22	3·20	1	1·09	2·25

From the above investigations, the following conclusions are drawn with regard to earthenware: (1) the biscuit oven must be fired to Cone 8 (1,250°); (2) the body must contain approximately 50% of clay substance; (3) the addition of felspar is necessary, or of twice the amount of Cornish stone, since the latter contains only one-half the quantity of alkalies. Body K, when fired to Cone 8, produces a very dense, solid ware.

TENTATIVE AND STANDARD METHODS OF TESTING.—(*J. Amer. Cer. Soc.*, **5**, *Year Book*, pp. 31–93, 1922). The Report of the Committee on Standards of the American Ceramic Society includes the following: Tentative method for sampling clay deposits; tentative method for sampling materials delivered: standard method for drying shrinkage; standard method for water of plasticity; standard method for shrinkage and pore water; standard method for behaviour in firing; standard method for softening point, standard method for the specific gravity; tentative method for ultimate chemical analysis; tentative method for sag tests; tentative method for transverse

strength ; tentative method for slaking ; tentative standard scale for testing sieves ; tentative definitions for clay refractories ; tentative methods of testing electrical porcelain ; tentative method of test for refractory materials under load at high temperatures.

IV.—MANAGEMENT, ORGANIZATION, COSTING, ETC.: COMMERCIAL.

CURTAILING WASTE BY COST ACCOUNTING.—A. P. Alford (*Brick*, **60**, 926, 1922). A group of about 50 engineers spent two months in making detailed field studies in about 125 industrial plants. Their report states that waste in industry is attributable to : (1) low production caused by faulty management ; (2) interrupted production resulting from men, materials, plants and equipment being idle ; (3) restricted production caused intentionally by owners, management or labour ; (4) lost production due to ill health, physical defects and accidents. The relative responsibilities of the various agencies for waste have been evaluated in "points." By "responsibility" is meant not moral responsibility in the ordinary sense, but only that responsibility which arises from the undeniable fact that a given cause of waste can be removed only by a particular agency. The percentage values for each of the agencies responsible in the six industries studied are as follows :

	Responsibility.		
	Against Management Per cent.	Against Labour Per cent.	Against Outside Contracts (The public, trade relationships, etc.) Per cent.
Men's Clothing Mfg.	75	18	9
Building Industry	65	21	14
Printing	63	28	9
Boot and Shoe Mfg.	73	11	16
Metal Trades ..	81	9	10
Textile Mfg. ..	50	10	40

The above figures appear to justify the following statement : "Over 50 per cent. of the responsibility for waste can be placed at the door of management and less than 25 per cent. attributed to labour, while the amount chargeable to outside contracts is least of all." It is suggested that the costs accountant is best fitted to carry out investigations such as these at intervals on a plant.

ECONOMIC HANDLING OF MATERIALS IN PORCELAIN MANUFACTURE.—A. P. Ball (*J. Amer. Cer. Soc.*, **5**, 235, 1922). The paper gives an outline of the manner in which modern practice in handling materials in metal working industries was applied to a dry process electrical porcelain plant. The savings effected in operating this plant were due almost entirely to more efficient handling of materials and not to changes in the existing manufacturing processes, which did not differ from those in general use on similar plants. The installation of a tunnel kiln, tunnel drier and other modern equipment would have had much the same result in saving, but at a far greater cost. The methods developed which differed from those commonly in use are described in some detail. Material, in various forms, was moved from the filter press to the pressing department, from the press room to the dryer, and from the dryer to the saggars by means of lift trucks, "skids" and racks. "Skids" were used throughout for storing all kinds of material except raw clay. Frames, 12-in. wide, were made to fit these skids, and were locked to the skid and to each other. For dry pressed ware, delivered from the press on boards, racks were secured to the skids ; similar racks were used for filter cakes. Any racks or skids could easily be moved by one man by

means of a lift truck. A total of 600 skids and racks were conveniently handled by eight lift trucks. The loaded saggars are lifted on to a belt conveyor running along the end of the loading bench, and are delivered by this means into the kiln. The saggars must be placed not less than 4-ft. apart on the conveyor, which is therefore marked off in lengths of 4-ft. By placing the rollers close together, it is claimed that even fairly unstable ware will ride satisfactorily. A serious problem was to devise a means for transferring the loaded saggars from the main conveyor to a conveyor travelling at right angles to it and leading into the kiln. This is accomplished as follows: The main belt conveyor is 14 in. wide and 180 ft. long and extends the full length of the kiln department past the six kilns. It is placed about 6 ft. above the floor, or 3 ft. above the kiln floor, and is located about 8 ft. from the doors of the kilns. Opposite each door, is a removable section, wide enough to permit the insertion at right angles of a short section of belt conveyor driven by a separate motor. This cross conveyor unit carries at one end two rollers which, when clamped into the place where the section is removed, depress the main belt sufficiently to provide clearance for the cross belt to fit in place at the same level as the main belt. Saggars travelling on the main belt strike the section of cross belt moving at right angles, rotate slowly as the cross belt secures traction and gradually alter their direction and move slowly into the kiln. Both conveyors move at the rate of 24 ft. per minute. The cross conveyor extends well through the kiln door and delivers the saggars on to a steel bench. The placer is in telephonic communication with the loading section so that he can direct the class of ware being placed to suit the position in the kiln where he is working. The cross conveyor can be changed from one kiln to another by two men in about half an hour. For the purpose of unloading a kiln, the under or return side of the belt conveyor is used. The fired ware, not being so fragile, a portable section of gravity roller conveyor is used instead of the belt conveyor, extending from inside the kiln to the main conveyor. It has a slight pitch and is provided with a curved section at the lower end, made with rollers of gradually reduced diameter. It was found necessary (owing to broken saggars, etc.) to place each saggar of fired ware on a wooden pallet before starting it on the gravity rollers. By means of the unloading belt and gravity conveyors, the fired ware is conducted into the inspection department, where the finished product is transferred to skid frames and moved by lift truck to the stores department.

Economies effected. Two placers in the kiln, with three or four loaders, depending on the class of ware, can load a kiln in 9 hours or less. By the old method, a gang of 8 or 10 men was required, working night and day (*i.e.*, about 20 hours), making a total of about 180 labour hours as against about 50 by the new method. Similar economies are effected in unloading, though direct comparison is difficult. Much breakage is said to be eliminated.

RATIONAL ANALYSIS; AN AID TO WORKS' CONTROL.—R. Rieke (*Ber. D.K. Ges.*, **3**, 24, 1922). A number of methods are discussed for rapidly determining the clay content of china clays. Preference is given to the Kallauner-Matejka method, by means of which the clay-substance content can be determined on a previously dried clay in 6 or 7 hours. The clay (about 2 grams) is first heated for an hour to about 750°C., preferably in a small electric furnace. This heat treatment breaks up the clay substance ($Al_2O_3 \cdot 2SiO_2 \cdot 2H_2O$) into free Al_2O_3 and SiO_2, the water of combination being driven off. If the temperature is not allowed to exceed 800°C., the whole of the free alumina will be dissolved in 100–150 cc. of dilute HCl (1 : 1), after heating over the water bath for 3 hours. If, however, greater stress is laid on quick than on strictly accurate results, the mixture may be heated over an open flame for 1 hour. The alumina in the filtrate, together with small quantities of iron oxide, is then precipitated with amonia, filtered, dried, ignited and weighed. From this result, the quantity of clay substance can easily be calculated. In addition to its rapidity, this method has the advantage of eliminating the use of (1) hot concentrated H_2SO_4, which attacks other constituents such as mica, and of (2) soda solution, which may have a

solvent effect on fine quartz. The HCl treatment, after calcining to 750°, will undoubtedly remove the alumina from any mica which may be present, but the quantity would be very small. Felspar and quartz are not affected in the least. A slight but unavoidable inaccuracy is associated with this method, in that the clay-substance content is calculated from the amount of alumina determined according to the accepted formula. Its superiority, as compared with three other methods (Berdel, Bollenbach, and Burian-Juranek), was further tested on a body containing kaolin, sand and Norwegian spar, which had previously been carefully prepared.

REDUCTION OF VARIETIES IN MANUFACTURED PRODUCTS.—E. W. McCullough (*J. Amer. Cer. Soc.*, **5**, 221, 1922). The many advantages of eliminating unnecessary and duplicated types of products are pointed out. The American paving-brick manufacturers and engineers succeeded in reducing a total of 66 styles to eleven. Further examples are quoted from other industries.

GERMAN EXPORTS OF POTTING TO THE U.S.A.—(*Brick*, **60**, 378, 1922). An account of conditions in the German industry.

WORKS ACCOUNTANCY; ITS RELATION TO PRODUCTION.—W. Campbell (*Eng. Ind. Man.*, **7**, 534, 1922).

DRAWING AND LOADING BRICKS AND TILES.—(*Brick Pot. Tr. J.*, **30**, 136, 1922). A few practical hints.

BRICK MAKING IN S. AFRICA.—(*Brit. Claywr.*, **31**, 91, 1922). An account of the Coronation Brick & Tile Co's works and methods at their plant near Durban (7 illustrations).

THE NEW ROCKLAND LIME PLANT.—N. C. Rockwood (*Rock Prod.*, **25**, No. 12, 36, 1922). An account, profusely illustrated, of an up-to-date lime plant.

SUGGESTED NEW METHODS IN THE PREPARATION OF DUST-PRESSED BODIES.—H. Spurrier (*J. Amer. Cer. Soc.*, **5**, 151, 1922). The use of a continuous pebble mill of the self-filling (Hardinge) type is recommended. There need be no misgiving with regard to the uniformity of the slip delivered from such a mill since there is no segregation due to difference in density, and the specific gravity of the constituents varies only between 2·58 and 2·65. A pebble mill has remarkably little effect on comparatively soft material such as corks, pieces of wood, rubber pump valves, intentionally put into these mills.

Instead of drying completely, wetting down, tempering, ageing and grinding the clay on leaving the presses, the author recommends drying the press cake only down to a water content of 16%, followed immediately by disintegrating and pressing. This means the removal of only 5–7% of water, with consequent great economy of time and steam. The pressed ware produced by this shortened procedure is very satisfactory. A further drying test was made, using a commercial humidity dryer, which required 6½ hours to reduce the moisture from 21·9% to 16% and tests showed that the clay was delivered very uniformly indeed.

The writer finally puts forward the proposal of combining the disintegrator and dryer, which suggestion, however, has not yet been put into practice. The suggested procedure is very much like that successfully practiced in the preparation of milk powder, and it is argued that the problems of producing milk dust and clay dust by this process are quite closely analogous, the clay problem being by far the simpler. A hot blast would be applied in a suitable manner to the clay as it leaves the mill for the disintregator, thus drying and disintegrating it in one operation. In a plant producing slip and dust by the methods outlined, the time saved would be very material. For one ton of clay mix figured dry a period of 8 hrs. 45 min. from bin to press-room was obtained.

GERMAN CHEMICAL STONEWARE.—M. Kaltenbach (*Chim. Ind.*, **7**,

424, 1922). An account of the conditions in the German heavy chemical industry. With regard to chemical stoneware, it is stated that the shapes are regular, and the grain size of delicate pieces, like valves, is of an extraordinary fineness. The resistance to acids and to variations in temperature is perfect. The German stonewares owe their superiority primarily to the fact that strict control is exercised over the clays, and the mixtures made up are carefully studied before being put into service. All work is checked in the laboratory, raw materials are pugged and mixed repeatedly, and finally allowed to weather for many months before using. Firing operations are controlled with pyrometers.

MODERN BRICKWORKS PRACTICE.—G. Zehner (*Tonind. Ztg.*, **46**, 590, 1922). The subject is discussed briefly under the following three headings: (1) Reduction of manual labour to a minimum; (2) minimum fuel consumption; (3) adaptability to the requirements of the moment accompanied by achievement of maximum output.

A NORMAL RATE OF PRODUCTION PLAN.—W. F. Godejohn (*Brick*, **60**, 846, 1922). Industrial conditions which approach the ideal are depicted. In order to avoid the great losses due to alternating periods of industrial activity and depression (trade cycles), it is proposed that a normal rate of production (65% of capacity) be maintained constantly, as far as possible. The matter is discussed with particular reference to a brickworks.

THE GERMAN HOUSEHOLD PORCELAIN INDUSTRY IN 1921.—(*Porz. Glas.*, **22**, 952, 1922).

THE DOMESTIC INDUSTRY IN CERAMICS.—O. Rebuffat (*Cer. Vet.*, **3**, No. 5, 1, 1921).

THE PRESENT CONDITION OF THE AMMONIA-SODA INDUSTRY IN JAPAN AND ITS FUTURE.—S. Nakahara (*J. Jap. Cer. Ass.*, 352, 624, 1921. Details of the demand for soda-ash in Japan and statistics on the soda industry in foreign countries are given. The ammonia-soda plant, which was established in 1917 by the Asahi Glass Co., manufacturers of window glass, has since had bitter experience, and is now manufacturing about ten tons of soda-ash a day. Raw materials, fuel and labour required for manufacturing one ton of soda-ash in March, 1921, were as follows: 1·9 tons salt (85%), 1·5 tons limestone (98%, 1·1 tons coal (with 22% ash), 0·2 tons coke (with 29% ash), 0·014 tons ammonia and 10 workmen (8 hours). Cheaper supply of salt and the prevention of dumping by foreign manufacturers are necessary to the further development of the industry. S. KONDO

V.—GLASS: GENERAL.

NEW DEVELOPMENTS IN THE AMERICAN GLASS INDUSTRY.—G. L. Montgomery (*Chem. Met. Eng.*, **26**, 788, 1922). An illustrated description of the Kimble Glass Co.'s plant at Vineland, N.J.

THE TRIUMPH OF MACHINERY IN UNITED STATES' GLASS WORKING.—(*Verre*, **2**, 122, 1922). A short historical sketch.

DEVITRIFICATION.—"Le Verrier" (*Verre*, **2**, 125, 1922). Devitrification is the result of the auto-separation of one of the alkaline-earth ingredients of a glass. This auto-separation gives rise to two distinct phenomena in the vitreous mass, both of which are due to one initial cause, viz.: prolonged heating at temperatures near the fusion point or solidification point (critical temp.). The first, and most common type, is due to the cristalloid separation of calcium monosilicate; it is merely a surface effect. The second type is due to nuclear separation, and represents an advanced stage of true devitrification. The hem. comp. remains unchanged, and investigations appear to support the hypothesis that glass is a solution of cristallized silicates in one or more amorphous silicates.

ON FLATTENING PLATE-GLASS.—O. Schrenk (*Sprech.*, **55**, 276, 1922) The causes of, and methods of avoiding, certain faults in flattening are discussed briefly.

ACID ETCHING AND POLISHING.—O. Schwarzbach (*Diamant*, **44**, 385, 1922). A brief account of the process, first introduced in America and France.

THE LAY-OUT OF POWER-DRIVEN GLASS-POLISHING WORKS.—W. Hannich (*Ker. Rund.*, **30**, 277, 1922).

"PHONOLITE" GLASS.—H. Kuhl (*Sprech.*, **55**, 313, 1922). Phonolite is a lava product, and contains large amounts of alkalies and alumina, together with about 2% of iron oxide. It can be used effectively for making strong coloured glasses. The following batch melts readily, giving a glass of a beautiful dark green colour : quartz sand 600 kg., soda 200, lime 80, barium nitrate 25, boric acid 30, phonolite 350, uranium oxide 6, pyrolusite 25 kg. A black glass is obtained with : 80 kg. ordinary gravel, screened to remove stones and lime, 40 kg. sulphate, 25 kg. lime, 2 kg. witherite, 100 kg. phonolite, 8 kg. carbon, 2 kg. sulphur and 4 kg. iron filings.

THE MANUFACTURE OF A THIN PLATE-GLASS.—J. Bauer (*Diamant*. **44**, 338, 1922). The patented process is as follows :—The glass is poured from the pots on to a flat plate, forming a thin sheet. This is allowed to solidify partially, and is then transferred to a heating oven. On becoming pliant and workable again, it is finished off by an "ironing" process. The glass is then annealed in the usual way.

MECHANICAL PLATE GLASS MANUFACTURE.—P. Simon (*Diamant*, **44**, 363, 1922). A short account of modern practice.

PYREX GLASS.—O. Lecher (*Sprech.*, **55**, 254, 1922). A description of the American glass, which is almost unbreakable, and is used for making cooking utensils. Comparative figures for the German glass 59 III., Pyrex glass and pure quartz glass are given :

	SiO_2	B_2O_3	Al_2O_3	Na_2O	Coeff. of Exp.
59 III. Jena glass ..	72	12	5	11	0·0000177
Pyrex glass.. ..	80·7	10·5	3·5	4·1	0·000004
Quartz ,, ..	100·0	—	—	—	0·0000015

PYREX GLASS.—W. K. (*Sprech.*, **55**, 285, 1922). In the last column of the comparative table given by Lecher (above), the figures for Jena glass 59 III. and for quartz glass must represent the cubical coefficients of expansion, whilst those for Pyrex glass refer to linear expansion. The correct figures should therefore be : 59 III. glass 0·0000177 ; Pyrex glass 0·0000120 and quartz glass 0·0000015.

A CRITICAL EXAMINATION OF METHODS COMMONLY USED IN DETERMINING THE DURABILITY OF GLASS.—W. E. S. Turner (*J. Soc. Glass Tech.*, **6**, No. 21, 30T., 1922). The methods discussed involve (1) the testing of the surfaces of glass vessels ; (2) the use of plates, discs or slabs ; (3) the treatment of the glass in powder form,: (4) the autoclave test. A standard test for durability should combine simplicity and accuracy, and the author suggests that it should be carried out either on plates or discs, or on powder.

ON APPARATUS FOR CONTROLLING THE ANNEALING OF GLASSWARE, AND ON ANNEALING WITHOUT PYROMETERS.—F. Twyman (*J. Soc. Glass Tech.*, **6**, No. 21, 45T., 1922). Various methods of annealing are discussed, and an account is given of some apparatus for the control of the process and for the determination of the annealing temperature.

AN EXAMINATION AND EXTENSION OF ZULKOWSKI'S THEORY OF THE RELATION BETWEEN THE COMPOSITION AND DURABILITY OF GLASSES.—W. L. Baillie (*J. Soc. Glass Tech.*, **6**, No. 21, 68T.,

1922). Zulkowski's theory is reviewed and applied to 27 optical glasses of known composition and durability. Certain modifications are proposed to enable certain types of glasses to be included for which the original theory has been shown to be inadequate. Both theories were applied to the results of experimental studies of the durability of 6 series of glasses (65 samples). The terms "basic excess" and "reactivity coefficient" are defined and their use is suggested. The new theory appreciably improves the agreement between the experimental gradings and the indications of Zulkowski's theory in the case of "crown" and "flint" glasses. Equally good results are obtained with glasses containing considerable proportions of Al_2O_3 and B_2O_3, where the original theory fails to explain the durability. Certain possible sources of discrepancies between reactivity coefficients and experimental results are indicated and discussed.

THE EFFECT OF MAGNESIA ON THE RESISTANCE OF GLASS TO CORRODING AGENTS AND A COMPARISON OF THE DURABILITY OF LIME AND MAGNESIA GLASSES.—V. Dimbleby, C. M. M. Muirhead and W. E. S. Turner (*J. Soc. Glass Tech.*, **6**, No. 21, 101T., 1922). The results of experiments are tabulated and plotted. It is concluded that magnesia glasses appear to possess a slight advantage over lime glasses in regard to corrosion by water; they show no advantage in the case of hydrochloric acid, and are decidedly inferior when the corrosive agent is an alkaline solution.

UNBREAKABLE EYE-GLASSES?—(*Glas-Ind.*, **33**, 158, 1922). Silex glass, which is capable of withstanding temperature variations of 400° and is almost unbreakable, cannot be used for eye-glasses owing to its extreme hardness. No satisfactory means have yet been found for grinding and boring this glass. Its use at present is limited to the manufacture of articles which can be blown or pressed.

THE CHEMICAL BASIS OF GLASS DECORATION AND GLASS ETCHING.—L. Springer (*Glashütte*, **52**, 289, 1922). The writer discusses the question: "What ought the glass painter, etcher, and mirror maker know about practical chemistry?"

MECHANICAL BOTTLE MANUFACTURE.—(*Verre*, **2**, 102, 1922). A description of the O'Neill machine, which functions entirely automatically.

THE MELTING OF GLASS.—(*J. Soc. Glass Tech.*, **6**, No. 21, 3T., 1922). A general discussion of the subject held at a meeting of the Society of Glass Technology, taking the form of "questions and answers."

THE ACTION OF VARIOUS ANALYTICAL REAGENTS ON CHEMICAL GLASSWARE.—W. E. S. Turner and T. E. Wilson (*J. Soc. Glass Tech.*, **6**, No. 21, 17T., 1922). Tests were carried out on three good types of chemical glassware with nitric acid, ammonium sulphide and sodium phosphate solutions. Nitric acid of sp. gr. 1·2 had only a very small corrosive action on all the glasses, and ammonium sulphide was on the whole still less corrosive. Both *N*/2- and *N*/4- sodium phosphate solution showed a distinct attack on all three glasses, increasing with strength of solution. The corrosive action of alkaline salt solutions does not appear to be due merely to alkalinity, since one glass, which compared very favourably with two others when caustic alkalies were the corroding agents was distinctly the more readily attacked by alkaline salt solutions such as sodium carbonate and sodium phosphate.

SOLUBILITY AND DECOMPOSITION IN COMPLEX SYSTEMS.—G. W. Morey (*J. Soc. Glass Tech.*, **6**, No. 21, 20T., 1922). It is pointed out that the action of water on complex silicate mixtures, whether crystalline or wholly or partially glassy, is one of decomposition. The distinction between compounds soluble in water and those decomposed by water is brought out by a consideration of the system $H_2O{\cdot}K_2O{\cdot}CrO_3$.

OPAL GLASS AND ALABASTER GLASS, AND THEIR APPLICATIONS.—K. Fuha and Y. Yoshioka (*J. Jap. Cer. Ass.*, 345, 302,

1921). A detailed historical survey of the manufacture and theory of opal glass and alabaster are given. (1) *Experiments.* The weight of each batch was 3 kg. for preliminary work, then it was increased to 10 kg. and finally 100–200 kg. batch was taken to manufacture various test pieces. The pot was heated by gas or heavy oil, and the temperature in the furnace was completely under control. (A) *Opal glass.* (*a*) Silica or alumina as opacifier. Soda-lime glass, containing more than 75% of silica, is sometimes devitrified in cooling or annealing. Aluminous hard glass also devitrifies in heating repeatedly. (*b*) Fluorine compounds as opacifier. In this case, glasses composed of 65–68% silica, 9–10% lead oxide, 8–10% alumina, 2–3% lime and 12–14% alkalies were used. The rôle of alumina is to reduce the corrosive action of fluorine compounds on the pot. On introducing varying amounts of fluorine to the glass, it was found that when felspar or amalgatolite is used as the source of alumina about 2·5 parts of fluorine per 100 parts of glass is required for the production of opal glass (irrespective of the kind of fluorine compounds, which include fluorspar, sodium fluoride, cryolite), whereas about 4% of fluorine is required when prepared alumina is used. (*c*) Bone-ash as opacifier. A deep opal glass was obtained by melting a batch composed of 1,200 sand, 800 litharge, 400 potash, 120 nitre, 75 borax, 20 arsenious oxide and 200 bone-ash, but it was translucent in the molten state. If we cool the glass to about 800°C. and heat is gradually to 1,000°–1,100° and maintain it at these temperatures, a translucent glass like alabaster will be obtained. Replacing potash with the same amount of soda-ash, no effect was observed. When the amount of bone-ash was reduced to 150 parts, a translucent glass was obtained ; a batch with 100 parts of it gave a transparent one. (B) *Alabaster glass.* (*a*) With fluorine compounds and auxiliary agents. Since it has been ascertained in the experiments of (1) (*b*) that translucent glasses are obtained by introducing about 2% of fluorine to the said glasses when felspar or amalgatolite is used, or by introducing about 3·5% of fluorine when alumina is used, these batches were used as bases. Experiments with these batches to which 0·5–3·0% of various auxiliary agents were added showed that the introduction of 1·5% or more of strontium or barium sulphate or 3·0% of calcium sulphate gave an alabaster glass. The efforts to use chlorides were unsuccessful but mixtures of sulphates and chlorides gave good results. The research resulted in placing "Johga Glass" on the market. (*b*) With asbestos. Asbestos batch, such as 1,000 sand, 380 potash, 125 litharge, 100 abestos and 40 nitre, gives a good alabaster glass when it is heated at a constant temperature for a certain time after it begins to melt. Melting at too high temperatures makes it transparent. (2) *Causes of translucency and opacity.* (A) Opal glass is produced (*a*) by setting free colloidal silica or alumina from glasses containing an excess of silica or alumina, (*b*) by similar cause from glasses containing flourine compounds. (*c*) or by dispersing calcium phosphate colloidally in a glass. (B) Alabaster glass is produced (*a*) by the suspension of minute or colloid particles of silica or alumina, together with gaseous substances, (*b*) by the suspension of minute substances or crystals of substances other than silica or alumina, *e.g.*, magnesium silicate, together with gaseous substances, (*c*) or by dispersing substances coarsely. Microphotographs are given. Microsections of Johga glasses show innumerable gas-bubbles, ranging from 10 microns to visible size. The physical properties were investigated and the results tabulated :—

	Reflection	Transmission	Absorption	Sp. gr.
An ordinary opal glass ..	70·0%	21·0%	9·0%	—
Johga glass No. 1 ..	36·7%	45·0%	18·3%	2·06
,, No. 2 ..	42·5%	49·4%	8·1%	2·66
,, No. 3 ..	45·5%	47·8%	6·7%	2·52

S. Kondo.

A NOTA ON OPTICAL GLASS.—R. Shibata (*J. Jap. Ass.*, 349, 481, 1921). Descriptions of several specimens of optical glasses, manufactured at the naval arsenal, Tokio, their materials, and the chief raw materials of the pots are given. The process of making pots is explained. S. Kondo.

STUDY ON THE LIFE OF POTS USED IN ROUND POT-FURNACES.—K. Ishikawa (*J. Jap. Cer. Ass.*, 350, 519, 1921). The study includes elaborate investigations extending over four years on 810 closed pots with a capacity of 600 lbs. of glass and 308 "Japan pots" with a capacity of 500 lbs. Furnaces with direct firing and those with semi-gas firing were used; in both cases, the flame, after ascending to the combustion chamber and playing around three to six pots, so arranged as to form a ring, was made to pass through the openings under the mouths of the pots. The life averaged 12 meltings for covered pots and 9·5 for "Japan pots." 75% of damages in the closed pot were caused by cracking, the remaining 25% being due to corrosion. 45·2% of cracks in the closed pots took place on the right and left sides. Different periods in which cracks appeared, the manner of growth of cracks, and the relation between parts of pots and the size of cracks are described. Damages due to corrosion took place chiefly at or near the bottom and at the level of the metal Various experiments were done to discover the cause of faults in glass at a factory where wares with stone or cord amounted to 19·09% at that time. Of the 19·09%, 3·8% were ascribable to the unskilfulness of workers, 8·4% to the age of the pots, 2·2% to corroded rings, 1·76% to corroded stoppers and 0·7% to too coarse sand; thus, only 2·23% were due to unknown causes. Pots with moderate weight had the longest life. Generally speaking, the slower they are dried, the better they wear. The life is also increased by storing the plastic body longer. It depends on the season of making and also on the size of the grains of the raw materials. The position of pots in the furnace has a remarkable effect. The temperature and durability of heating pots in the pot arch are discussed.
S. KONDO.

COLOUR OF GLASS IMPARTED BY IRON.—K. Fuha (*J. Jap. Cer. Ass.*, 354, 39, 1922). Over one thousand and five hundred different batches were melted to ascertain the effect of variation in the composition of glass and the influence of oxidising or reducing agents on the colour of glass imparted by iron. Pure chemicals and ground rock-crystals were used. Three formulas were used as bases: (1) R'_2O, R''O, $3SiO_2$, (2)R_2 O.R''O, $0{\cdot}5B_2O_3$, $3SiO_2$, and (3) $1{\cdot}3R'_2O$, $0{\cdot}7R''O$, $6SiO_2$, where R'_2O represents K_2O or Na_2O and R''O represents CaO, MgO, ZnO, BaO or PbO. Glasses belonging to (1) or (2) were melted at 1,300°–1,350°C. while those of (3) were melted at 1,400°–1,550°C. The colour imparted by ferric oxide is described. Generally speaking, it colours soda glass blue or bluish green and potash glass yellowish green or green. The increase in the colorant adds a yellow shade to soda glasses and a blue shade to potash glasses. However, there are exceptions where no difference is observable between soda and potash glasses. The difference in R''O affects the colour, *e.g.*, ferric oxide imparts dark reddish brown to Na_2O, BaO, $3SiO_2$, light blue to Na_2O, CaO, $3SiO_2$, dull blue to Na_2O, ZnO, $3SiO_2$. and yellowish tint to Na_2O, PbO, $3SiO_2$. Boric acid does not affect the colour although sometimes it darkens or brightens the colour. In addition, detailed descriptions are given of (1) the colour imparted by ferrous oxide, ferric chloride, ferrous sulphate, ferrous carbonate or ferrous oxalate, (2) the effect of sodium carbonate or potassium carbonate on the coloration of ferric or ferrous oxide and (3) the effect of potassium-sodium tartarate or arsenious acid on the colour imparted by ferric or ferrous oxide. S. KONDO

STUDY OF CHEMICAL GLASS WARE.—T. Ogawa (*J. Jap. Cer. Ass.*, 355, 91; 358, 252, 1922). The results of chemical analyses and tests on the resistance to chemicals, impact and sudden change in temperature of foreign and domestic chemical glass wares, as well as those made by the author, are given. In general, home products are inferior to foreign ones, owing to their improper compositions. Furnaces producing high temperatures and pots capable of withstanding them are indispensable for manufacturing chemical glasses of the best quality, since the constituents of glass which increase its resistance to chemicals make it more refractory. Batches containing proper proportions of zinc oxide, alumina, magnesia, boric acid and silica suit furnaces with semi-gas firing. The use of sands containing alumina, felspar, or dolomite is economical. S. KONDO.

ON THE SURFACE DEVITRIFICATION OF SHEET GLASS.—Y. Amenomiya, K. Kojima and H. Ota (*J. Jap. Cer. Ass.*, 356, 137, 1922). The paper relates to the surface devitrification of finished sheet glasses by heat treatment. An electric furnace was used. The microphotographs of several sheet glasses of two factories, which had been heated to various temperatures, indicate that the temperature at which crystals begin to appear is about 700°C. The crystals produced at this temperature are spherulitic, while they are changed to radiating needles by heating at 750°. At 900°, the crystallisation proceeds into the interior of the glass and it becomes a white sheet. At certain higher temperatures, the crystals melt and disappear; these temperatures were 985°–1,130°C. for eight kinds of sheet glass. The relation between devitrification and time of heating at various temperatures is discussed. The time required for the devitrification which occurs in cooling a molten glass is far longer than that required for the devitrification in heating up. S. KONDO.

PATENTS.

MAKING GLASS TEST TUBES.—P. Bornkessel (*Pat. J.*, 1,741, 1922). No. 177,884, Jan. 7, 1921. Relates to automatic apparatus for making two tubes, with one end closed, from a single open-ended tubular blank.

CUTTING, OR GRINDING GLASS.—J. E. Marsden (*Pat. J.*, 1,741, 1922) No. 178,063, Aug. 25, 1921. Describes a machine for gripping and rotating glass articles to be decorated by cutting or grinding.

BOTTLE-BLOWING MACHINE.—J. Wolf (*Pat. J.*, 1,745, 1922). No. 179,422, Apr. 27, 1921. Relates to a pneumatically operated hand-controlled bottle-blowing machine of the suction gathering type.

IMITATION PEARLS.—L. Bonnet (*Pat. J.*, 1,745, 1922). No. 179,527, Apr. 20, 1922. Imitation pearls in glass or enamel are formed on a solid metal wire provided with a thin coating of friable or refractory material, such as a mixture of alumina and kaolin, to prevent the fused material adhering to the wire. The latter is held in a frame and is made to rotate. A hand rest is provided for the operator, who holds a blowpipe and a rod of glass or enamel.

GLASS TANK FURNACE WITH REGENERATOR.—J. S. Atkinson and Stein & Atkinson, Ltd. (*Pat. J.*, 1,756, 1922). No. 183,373, Aug 26, 1921. Describes an arrangement of gas and hot air passages and of burners.

METAL MOULDS FOR GLASS WORKING.—R. L. Frink (*Pat. J.*, 1,757, 1922). No. 183,582, Apr. 26, 1921. Metal moulds with a porous or finely pitted surface are made from an alloy of aluminium or copper with calcium, barium and magnesium.

SHEET-DRAWING APPARATUS.—W. J. Mellersh-Jackson (*Pat. J.*, 1,758, 1922). No. 184,053, July 28, 1921. Spec. 114,977 is referred to. The invention consists in reheating the sheet, *e.g.*, by gas jets, at the point where it leaves the roll.

AUTOMATIC GLASS-SHAPING MACHINE.—Hartford-Fairmount Co. (*Pat. J.*, 1,758, 1922). No. 184,171/2, July 25, 1922. In the machine, the moulds are arranged in pairs, a parison mould and a blow mould, adapted to turn about a common axis so as to invert the moulds and reverse their positions.

GLASS FURNACES.—F. O'Neill (*Pat. J.*, 1,747, 1922). No. 179,977. Relates to apparatus for delivering uniform charges of molten metal from a tank furnace.

GLASS MANUFACTURE; VALVES.—M. White (*Pat. J.*, 1,749, 1922). No. 180,895, May 28, 1921. Relates to a method of timing the valve of glass-working machinery while the machine is in motion.

SHEARING MECHANISM.—M. White and A. E. Clegg (*Pat. J.*, 1,750, 1922). No. 181,233, May 28, 1921. Relates to mechanism for use with flow feed delivery apparatus.

DRAWING GLASS CYLINDERS.—Empire Machine Co. (*Pat. J.*, 1,750, 1922). No. 181,308, Sept. 6, 1921. Apparatus is described for drawing cylinders, particularly from a body of metal contained in the forehearth of a tank. The glass is cooled more on one side than on the other, in order to secure cylinders, of even thickness.

GLASS PRESSING.—E. A. Hailwood (*Pat. J.*, 1,751, 1922). No. 181,434. Description of a device for pressing articles from glass, comprising a mould, a cup for measuring the quantity of glass, and a device for giving the article an auxiliary or secondary squeeze after it has been formed in the mould.

GATHERING MOLTEN GLASS.—H. Blanc (*Pat. J.*, 1,752, 1922). No. 182,011, July 27, 1921. Describes a method of gathering molten glass for delivery to forming machines. Part of the metal in a tank is cooled, some of the cooled metal is withdrawn and then reheated to restore fluidity.

GLASS-ANNEALING FURNACE.—Soc. des. Verreries de Folembray (*Pat. J.*, 1,753, 1922). No. 182,109, June 16, 1922. A gas-fired annealing tunnel or arch is heated by two sets of burners, one set arranged in the usual way in the roof, the others beneath the sole or in other suitable position. These deliver into a combustion chamber separated from the annealing chamber by heat-absorbing chequer brickwork.

PLATE GLASS MANUFACTURE.—A. W. Mathys (*Pat. J.*, 1,754, 1922). No. 182,551, Apr. 1, 1921. High-grade plate glass is produced by a double-roll machine, similar to the Chance machine. According to the invention, the whole refined contents of a melting pot are charged in one mass into a rolling mechanism, the resulting plate being received on a travelling plate.

GLASS BOTTLE-MAKING MACHINES.—J. Middleton and B. Wilson and Glassworks Ltd. (*Pat. J.*, 1,754, 1922). No. 182,664, June 4, 1921. Relates to machines of the stationary type in which turnover heads are manually operated.

MAKING ARTICLES OF SILICA GLASS.—Deutsch-Englische Quarzschmelze Ges. and Z. von Hirschberg (*Pat. J.*, 1,754, 1922). No. 182,781, June 26, 1922. A method of manufacturing hollow articles of fused quartz, such as dishes, cups, crucibles, etc., consists in producing a tubular blank by the usual methods, cutting the tube into separate small blanks of concavo-convex form, placing the sections upon cores shaped according to the article being made, and then submitting the covered cores to the action of a high-temp. flame, such as an oxy-hydrogen jet, so that the blanks assume the shape of the cores, and at the same time are glazed and become impervious to gases.

DRAWING GLASS.—E. Rowart (*Pat. J.*, 1,754, 1922). No. 182,805, July 5, 1922. In drawing glass in continuous sheets, the width of the sheet is preserved by drawing the edges from metal which issues from channels in refractory blocks. Means are provided for regulating the temp. and consistency of the body of the metal.

VI.—CEMENT, CONCRETE, MORTARS, ETC.

MANUFACTURE OF MAGNESIUM OXYCHLORIDE CEMENT.—(*Rock Prod.*, **25**, No. 15, 15, 1922). The maximum concentration of the magnesium chloride solution used is round about 22 deg. Baumé. The calcined magnesite should be finely ground, so that at least 97% passes a 100-mesh, and at least 75% passes a 200-mesh.

QUALITY CONTROL IN CEMENT MANUFACTURE.—R. K. Meade (*Rock Prod.*, **25**, No. 15, 25, 1922). Fineness of grinding, and time and

temperature of burning are important factors affecting quality. Some practical solutions of these mechanical rather than chemical problems are proposed.

A NEW CEMENT.—(*Gas World*, **77**, 145, 1922). A cement, impervious to water and oils, consists of a mixture of zinc or magnesium and ammonium chloride with zinc or magnesium oxide, which react, forming oxychlorides. A hardening agent is added, such as powdered glass, sodium biborate, silica and flowers of zinc, which are mixed with the oxides. When set, contact with water increases the hardness. The final product is impervious to water and oils and is unaffected by organic liquids. The durability may be increased by the addition of very finely powdered iron free from oxide.

CONCRETE ROAD CONSTRUCTION IN ILLINOIS.—(*Cement Eng. News*, **34**, No. 7, **29**, 1922). An account of the modern methods applied.

CEMENT ROOFING TILES.—C. R. Platzmann (*Tonind. Ztg.*, **46**, 851, 1922).

THE EFFECT OF ALKALI UPON CONCRETE.—S. H. McCroy (*Cement Eng. News*, **34**, No. 6, 17, 1922). The decomposition of concrete when in contact with solutions of alkaline salts is caused by chemical reaction between the lime of the cement and the salts (NaCl, Na_2SO_4, $MgSO_4$, $CaSO_4$, $CaCO_3$, etc.) in solution. Minute crystals are first observed in the concrete, and as the action progresses a chalky band forms near the surface. This band gradually widens, causing swelling and cracking of the concrete. Alternate wetting and drying, freezing and thawing, aggravate the trouble. No satisfactory preventive has yet been found. The concrete should be as dense and impermeable as possible. In choosing materials, limestones, dolomites and sandstones should be avoided.

INTERPRETING THE CHEMICAL ANALYSIS OF PORTLAND CEMENT.—J. C. Witt (*Cement Eng. News*, **34**, No. 6, 21, 1922). The percentage of the various components of a cement cannot be determined directly since they contain the same elements in common. The system of recasting results of chem. anal. has not demonstrated any definite relationship between such results and the behaviour of the cement under physical tests. A system of indirect analysis is subject to so many errors that the results obtained are unreliable.

SELECTING AND PROPORTIONING SAND-ASPHALT PAVING MIXTURES.—P. Hubbard (*Rock Prod.*, **25**, No. 11, 37, 1922).

THE BEHAVIOUR OF HYDRAULIC CEMENT IN WATER CONTAINING SULPHATES.—Herrmann (*Tonind. Ztg.*, **46**, 787, 1922). The results are given of a number of experiments on different cements, extending over lengthy periods. The destructive action of sulphate water is due to the formation of the double salt of calcium-aluminium-sulphate, the sharp, needle-like crystals of which exert a powerful disruptive influence. A dense concrete is less susceptible to this destructive action than a porous one. The mixture should therefore contain 1 vol. of Portland cement to not more than 2 of sand ; or, if 0·7 vol. of Rhenish trass is added to the Portland cement, more sand may be used. With iron-Portland cement, only 0·5 vols. of trass are required. For certain purposes, special blast furnace cements, requiring no trass, may be used. The cement may be protected with a hot coating of asphalt mixture, or with asphalt-bitumum sheeting soaked in tar.

A NEW AUTOMATIC ROTARY GRATE SHAFT KILN FOR PORTLAND CEMENT.—T. F. Miller (*Chem. Trade J.*, **71**, 130, 1922). A description is given of a new kiln patented by Curt von Grueber, Berlin. An 8 ft. diameter kiln will produce over 50 tons of well-burnt clinker in 24 hours with a fuel consumption of 16% of the finished product. The quality is equal in every way to the cement obtained from rotary kilns.

HOLLOW CONCRETE BUILDING BLOCKS.—Probst. (*Tonind. Ztg.*, **46**, 598, 1922). Production and wages figures are quoted to show that

hollow block construction is approximately 20% cheaper than ordinary brickwork. This is due mainly to economy in wages and in mortar.

MINERAL AGGREGATE SPECIFICATIONS FOR ASPHALT PAVEMENTS.—R. M. Green (*Rock Prod.*, **25**, No. 10, 34, 1922).

THE TEMPERATURE REQUIREMENTS OF CEMENT KILNS AND THE PROPERTIES OF THE GASES OF COMBUSTION.—A. Heiser (*Tonind. Ztg.*, **46**, 631, 1922). A theoretical discussion. The method of arriving at the theoretical flame temperature, etc., in a rotary furnace fired with powdered coal of given composition is outlined.

THE EFFECT OF ATMOSPHERIC CONDITIONS ON THE INITIAL SET OF CEMENT.—C. L. Jenken (*Cement Eng. News*, **34**, No. 5, 33, 1922). At Phoenix, California, it was found that the fresh concrete would often take its initial set in the pavement so rapidly, that within 30 min. after mixing, belting of the surface was almost impossible. Laboratory tests proved that the extreme dryness and high temp. which prevails at P. from June 15 to Sept. 10, were responsible for this peculiar behaviour of the cement.

MIXING LIME AND TRASS IN THE MOST FAVOURABLE PROPORTIONS.—H. Burchartz (*Mitt. Materialprüfungsamt, Berlin*, **39**, 240, 1921). The tensile strength and crushing strength of various mixtures were determined and the data tabulated (10 tables). It was found that (*a*) the crushing strength increased at first with the addition of lime up to a certain maximum, which varied with the different kinds of lime employed, after which further additions had the opposite effect ; (*b*) parallel curves were obtained for 90-day and 28-day samples ; (*c*) in two instances the variations in tensile strength with increasing lime content differed from those of the crushing strength. With regard to the most favourable mixing proportions, it is concluded that : (1) with standard lime, the best results as regards crushing strength are obtained with a mixture of trass and lime in the proportion of 1 : $1\frac{1}{2}$, but the maximum tensile strength is obtained with less lime (with mixtures of approximately 1 : 1, or less) ; (2) with sack lime, containing less free lime, the best mixtures for crushing strength are in the proportion of 1 : 2, and for tensile strength 1 : 1.

THE SETTING AND WATER-BINDING OF PORTLAND CEMENT.—(*Tonind. Ztg.*, **46**, 663, 1922). A brief discussion, including the results of work recently published by the American Bureau of Standards and the Geophysical Laboratory.

NEW DEVELOPMENTS IN OXYCHLORIDE STUCCO AND FLOORING.—J. B. Shaw and G. A. Bole (*J. Amer. Cer. Soc.*, **5**, 311, 1922). Calcium chloride can be substituted for magnesium chloride only under special conditions. Substitution of dolomite for magnesite would materially reduce the first cost of the cement. Calcium chloride solutions must be much more dilute than magnesium chloride. Less filler can be used with the latter. Mixtures of the two chlorides do not give such good results as either separately. Figures are given for tensile strength, volume change, weathering tests, and specific gravity of dolomite—calcium chloride and dolomite—magnesium chloride cements. Some good cements were found. Excellent cements of the latter type are reported, equal to magnesite cements of equal MgO content.

ACCELERATED TESTS OF PORTLAND CEMENT.—S. Kano (*J. Ind. Chem., Tokio*, **7**, 657, 1921). Methods hitherto proposed for the rapid testing of Portland cement are described and discussed. Two Portland cements with the following compositions were used throughout the study :

Cement	Insol. residue	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	Loss on ignition	Total
A	0·20	24·42	3·80	3·25	63·52	1·03	0·97	2·10	99·29
B	0·17	4·67	4·61	3·20	63·79	1·72	1·02	1·75	99·93

Thin pats of both cements stood the four-week cold-water test, but in the boiling test of an hour and a half, the pats of *B* were badly cracked, while

those of *A* remained sound. To see the effect of heating the briquettes during their hardening on the strength of cement mortars, test pieces which had been allowed to remain in moist air for twenty-four hours were immersed in water at ordinary temperatures, and then the whole vessel was put in a larger tank containing boiling water which brought the temperature of the water in the inner vessel to 97°–98°C. in about an hour and a half. Some of the results are given in the following tables :—

		CEMENT A			CEMENT B		
		Tensile Strength		Crushing Strength	Tensile Strength		Crushing Strength
		Neat Cement	Cement 1 Sand 3	Cement 1 Sand 3	Neat Cement	Cement 1 Cement 3	Cement 1 Sand 3
Per cent. of water used :		14·5	7·5	7·8	14·5	7·0	7·5
Temp.	Age of hardening.						
97°–98°	1 day ..	32·3	11·0	48·0	—	—	—
,,	2 days ..	75·8	15·9	182·0	75·0	16·4	162·1
,,	3 ,, ..	84·1	20·3	234·0	86·8	19·8	217·0
,,	4 ,, ..	66·6	21·0	258·5	93·6	21·0	258·0
,,	5 ,, ..	71·1	22·0	278·5	77·8	21·9	270·0
,,	6 ,, ..	73·4	21·4	285·5	78·1	21·1	301·0
,,	7 ,, ..	77·1	23·1	302·5	76·1	22·5	303·0
8·–18°	7 ,, ..	66·4	22·5	131·5	61·8	21·0	117·0
,,	28 ,, ..	68·9	30·3	106·5	65·9	29·0	181·0

Thus, the tensile strength of neat cement mortar, when it is hardened at high temperatures, attains a maximum within three or four days and then falls rapidly. A similar phenomenon is also observable in cement-sand mortar, though it is much less pronounced. Since such an irregularity does not occur in the crushing strength, its test is more reliable than that of tensile strength. The expansion of these cements hardened at ordinary and high temperatures was measured :

Expansion of Neat-Cement Mortar, measured with Bauschinger's Apparatus, at 15°C.

	CEMENT A		CEMENT B	
	Hardened at ord. temp.	Hardened at high temp.	Hardened at ord. temp.	Hardened at high temp.
Time of hardening	0·0303%	0·0808%	0·0287%	0·1442%
3 days ..	0·0386	0·0832	0·0481	0·1570
7 ,, ..	0·0424	0·0674	0·0538	0·1468
14 ,, ..	0·0547	0·0694	0·0650	0·1468
21 ,, ..	0·0547	0·0694	0·0650	0·1468
28 ,, ..	0·0590	0·0688	0·0758	0·1504

The reason why cement *B* failed in the boiling test for soundness is clearly explained in the table. In addition, the moisture content and loss on ignition of test pieces, made in a similar manner, were also determined. S. Kondo.

FIREPROOFING WITH GYPSUM.—J. F. Cameron (*Rock Prod.*, **25**, No. 17, 18, 1922). A well-illustrated description of a plant which has been rendered fireproof by applying gypsum to the wooden structure.

ON THE MANUFACTURE OF GYPSUM.—(*Kalk Schm. Ztg.*, **29**, No. 16, 1922). A short, general discussion.

PATENTS.

MOULDING CONCRETE BLOCKS.—J. H. Harrison (*Pat. J.*, 1,745, 1922). No. 179,399, Apr. 7, 1921. The machine has a reversible mould adapted to be raised after reversal to discharge the block. The journals, on which the mould is pivoted, are raised and lowered by overhead gear.

BUILDING BLOCKS.—W. Wilkie (*Pat. J.*, 1,747, 1922). No. 180,169. To prevent the passage of moisture, a plate of iron is interposed in the centre of a concrete block.

BUILDING BLOCKS.—E. Doherty (*Pat. J.*, 1,747, 1922). No. 180,181. Describes a special shape.

MOULDING CONCRETE BLOCKS.—W. Marriott, A. W. Roy and A. Ramm (*Pat. J.*, 1,751, 1922). No. 181,408. Describes a rotary-table machine.

MOULDING CEMENT, ETC.—E. W. Roberts (*Pat. J.*, 1,752, 1922). No. 181,745, Mar. 21, 1921. Hollow objects are moulded by introducing into a mould an easily-flowing mixture containing an excess of water and compressing the mixture within the mould by means of an expansible core to expel the excess water.

CEMENT MANUFACTURE.—Merz & McLellan (*Pat. J.*, 1,752, 1922). No. 181,811, Mar. 17, 1921. The invention comprises a kiln plant and a process for operating it. The kiln is fired by coke residue from a carbonization plant working in conjunction with it.

COATING STONE.—W. Schneider (*Pat. J.*, 1,753, 1922). No. 182,213, Mar. 30, 1921. A mixture of sulphur, graphite, small shot and Portland cement or plaster of Paris, is made into a paste with water and applied to natural or artificial stone. After the cement has set, a hot smoothing iron is passed over the coating to melt the metal and produce a metallic surface.

CONCRETE MOULDS.—J. Bluan (*Pat. J.* 1,753, 1922). No. 182,309, June 18, 1921. Describes a mould consisting of a loose bottom supported on a table and arranged so that the frame can be lowered after formation of the block.

BUILDING BLOCKS.—A. Knapen (*Pat. J.*, 1,754, 1922). No. 182,682, June 29, 1921. The passage of heat through building blocks of cement, mortar, etc., is prevented by introducing rows of air spaces, the width of which increases from the outer to the inner surface of the block.

MIXING CONCRETE.—E. H. Arnold and A. W. Dixon (*Pat. J.*, 1,758, 1922). No. 183,949, May 11, 1921. A description is given of an intermittingly rotating drum, divided into compartments, for measuring and delivering the ingredients of concrete to the mixing machine.

MOULDING CONCRETE TUBES.—J. Skorkovsky (*Pat. J.*, 1,739, 1922). No. 177,294, Jan. 13, 1921. Reinforced concrete tubes are made by feeding the concrete continuously and under pressure into the mouthpiece of a press, and simultaneously feeding horizontal rods around which a wire is wound in a spiral.

BOX MOULD FOR CONCRETE BLOCKS.—W. Wilkie ((*Pat. J.*, 1,739, 1922). No. 177,229, Dec. 18th, 1920. Describes a box mould for blocks and slabs, of which the front, sides and cover are hinged and slidable.

REINFORCED CONCRETE STRUCTURES.—H. Coanda (*Pat. J.*, 1,740, 1922). No. 177,543, Mar. 25, 1922. Walls, floors, roofs, and pillars are formed by assembling precast semi-cylindrical or arched reinforced concrete ribs, and filling in the spandril spaces with concrete.

HOLLOW BUILDING BLOCKS.—J. J. S. Barker (*Pat. J.*, 1,740, 1922). No. 177,593, Dec. 24, 1920. Description of a hollow building-block of concrete, clay, terra-cotta, etc., comprising an external and an internal portion,

both provided with through cavities and connected by a web, forming cavities at each end of the block.

MOULDING BUILDING BLOCKS.—E. C. R. Marks (*Pat. J.*, 1,741, 1922). No. 177,814, Sept. 23, 1920.

CONCRETE MIXER.—J. Southall (*Pat. J.*, 1,741, 1922). No. 177,977, Mar. 16, 1921. A corrugated drum, formed in segments, is supported on rollers mounted on shafts by which the drum is rotated automatically in opposite directions.

MOULDING CONCRETE PIPES.—J. Graber (*Pat. J.*, 1,741, 1922). No. 178,060, July 20, 1921. Description of apparatus.

MOULDING AND COLOURING ARTIFICIAL STONE, ETC.—B. R. Whitby (*Pat. J.*, 1,743, 1922). No. 178,736, May 10, 1921. One side of a glass plate is filmed with cement mixture coloured as required, the film is allowed to set on the glass, which is then placed as a removable lining in a mould, the latter being finally filled up with cement, concrete, etc.

MOULDS FOR CONCRETE BLOCKS.—J. Stewart (*Pat. J.*, 1,744, 1922). No. 178,870, July 25, 1921. Description of a mould with adjustable sides for making blocks of different sizes.

PLASTIC COMPOSITION.—M. Greene (*Pat. J.*, 1,744, 1922). No. 178,880, Nov. 27, 1920. A mixture for covering walls, floors, and for making moulded articles contains 33 lb. magnesite rendered caustic, 11 lb. wood-meal, and 5 lb. limestone meal mixed into a stiff paste with a 20% solution of magnesium chloride. 2½ lb. talc and 2½ lb. colouring matter may be added.

CONCRETE.—A. Hambloch (*Pat. J.*, 1,744, 1922). No. 179,029, Mar. 14, 1921. An aggregate for use in light concretes consists of pumice which has been separated from heavy impurities by water, comminuted until it resembles a mixture of sand and gravel, and artificially dried. The grains are then coated with a cement or lime magma, and air-dried.

ARTIFICIAL STONE.—R. Lamarque (*Pat. J.*, 1,745, 1922). No. 179,204, Oct. 29, 1920. Natural stone is crushed and graded by sifting, or washing, until a dust-free product of uniform fineness, corresponding to the natural grain of the stone, is obtained. Pure or mixed cement, coloured or otherwise, burnt or wet clay, or kaolin, may be used as binders. The composition may be applied to a core of reinforced concrete. After treatment with acids to remove calcium salts, the surface can be polished in the usual way.

MOULDING CONCRETE BLOCKS.—T. A. Brown & C. Walker (*Pat. J.* 1,732, 1922). No. 174,748, Nov. 3, 1920. The machine comprises a mould with retractible sides and vertically moveable bottom.

MOULDING CONCRETE BLOCKS.—J. B. Harvey (*Pat. J.*, 1,733, 1922). No. 175,105, Nov. 24, 1920. Relates to machines for moulding blocks, in which the moulds rotate about a cam and are arranged to open, so that the blocks can be removed by hand.

CONCRETE AND COMPOSITE VESSELS.—G. C. and K. E. Newton (*Pat. J.*, 1,734, 1922). No. 175,487, Dec. 18, 1920. Vessels are built up with pre-cast concrete or pre-fabricated steel ribs and frames. The ribs are formed with outwardly-projecting skin reinforcements which extend in the plane of the skin. When the ribs are of pre-cast concrete the skin may be cast with a different kind of concrete.

PAVING BLOCKS.—G. Yamanouchi (*Pat. J.*, 1,737, 1922). No. 176,730, July 29, 1921. An angular ferro-concrete block has a base recess, the edge of which is notched, and a central vertical hole, through which concrete mortar is poured.

ARTIFICIAL MARBLE.—Arajiro Hisada (*Jap. Pat.* No. 38,873, June 11, 1921). Elastic porcelain bodies of different colours are cut to irregular pieces and thrown together in a mould, and the mould is filled with a similar

body of white or other colour and pressed. The shaped body is fired after drying. The surface of the fired product is sometimes polished. S. KONDO.

VII.—CHEMICAL AND ANALYTICAL PROCESSES.

THE INTERACTION OF SODIUM CHLORIDE AND SILICA.—F. H. Clews and H. V. Thompson (*J. Chem. Soc.*, **121**, 1,442, 1922). The reactions were carried out in silica tubes, fixed horizontally through an electric resistance furnace, the materials being introduced in a platinum boat. A purified stream of the requisite gas, dry or moist, was passed through the tube, and the products of the reaction were absorbed in *U* tubes containing moistened fragments of silica. The temp. employed varied between 569° and 1,045°. The reactions involved are: (*a*) $4x\mathrm{NaCl}+y\mathrm{SiO_2}+x\mathrm{O_2}=2x\mathrm{Na_2O}, y\mathrm{SiO_2}+2x\mathrm{Cl_2}$; (*b*) $2x\mathrm{NaCl}+y\mathrm{SiO_2}+x\mathrm{H_2O}=x\mathrm{Na_2O}, y\mathrm{SiO_2}+2x\mathrm{HCl}$; (*c*) $4\mathrm{HCl}+\mathrm{O_2}=2\mathrm{H_2O}+2\mathrm{Cl_2}$. Reaction (*a*) occurs in a current of dry air, (*a*), (*b*) and (*c*) in moist air, and (*b*) in moist nitrogen. In moist air, reaction (*b*) predominates. It is just discernible at about 600° and is very small up to 1,000°. Rise of temp. and increase in supply of moisture facilitate the reaction. The proportion of NaCl has only a subsidiary effect, the area of contact being the important factor. At 1,000° NaCl converts quartz into tridymite, probably owing to solution and recrystallisation. Of the different varieties of silica investigated—quartz, precipitated silica, and tridymite—quartz is the most reactive to NaCl at 1,000°.

AN INVESTIGATION OF THE FORMATION OF LAYERS IN CLAY SUSPENSIONS AND THEIR APPLICATION IN SOIL ANALYSES TO DETERMINE THE SIZE OF PARTICLES.—E. Ungerer (*Kolloidchem. Beihefte*, **14**, 63, 1921; *Ber. D. K. Ges.*, **3**, 43, 1922). The method of applying Stokes' formula is discussed. The formation of layers must be considered as due to the size and weight of the individual particles. Each layer corresponds to a definite size of particle. There are distinct differences between the various layers as regards size and weight of the particles. The suspension between two layers is of uniform concentration. Constant temperature is an important factor in the formation of layers. Layers are formed in suspensions with or without electrolytes, though a high electrolyte content would prevent their formation owing to the coagulating effect. The individual layers fall (or rise) at a uniform rate. With the aid of Stokes' formula, the size of the particles forming each layer can be determined from the velocity of sedimentation.

COLLOID CHEMISTRY; THE STRUCTURE THEORY.—R. Zsigmondy (*Zeits. angew. Chem.*, **35**, 449, 1922).

COLLOIDS AND THEIR PRINCIPAL APPLICATIONS.—P. Razons (*Ind. Chem.*, **9**, 287, 1922).

THERMAL ANALYSIS AS A MEANS OF DETECTING KAOLINITE IN CLAYS.—J. Matejka (*Chem. Listy*, **16**, 8, 1922). Abstract taken from *Chim. Ind.*, **7**, 1,154, 1922. In order to discover whether thermic analysis could be applied to determine kaolinite in clays, the author first tested the accuracy of the method when other bodies besides kaolinite were present. Dehydration is endothermic in character at 570—580°C. It is characteristic of the material examined, and can be utilized to determine the kaolinite. The heating curves published by the author show an almost horizontal section between 570 and 580°, the length of which increases with the proportion of kaolinite present in the clay. When equal weights of different clays are employed, the horizontal sections not only indicate the presence of kaolinite, but also enable the proportion of the latter to be calculated approximately. To do this, the following conditions must be fulfilled: The weight of the

sample must not be less than 5 gr. and it must contain at least 3% of kaolinite. The presence of orthoclase, lime, mica, quartz, or bauxite does not interfere with the normal dehydration process of kaolinite. It simply has the effect of shortening the horizontal section of the heating curve. On the other hand, the presence of magnesite prevents the determination of kaolinite in clays. It is therefore essential to digest the sample with HCl before proceeding with the thermic analysis.

A CENTRIFUGAL METHOD FOR PREPARING COLLOIDAL FERRIC HYDROXIDE, ALUMINIUM HYDROXIDE AND SILICIC ACID.—R. Bradfield (*J. Amer. Chem. Soc.*, **44**, 965, 1922). A method is described for preparing colloidal ferric hydroxide, aluminium hydroxide and silicic acid from the fresh precipitates of these substances by the removal of the excess of precipitating agent by thorough washing by means of a supercentifuge.

ELECTRO-OSMOSIS AND ITS APPLICATIONS.—(*Chem. Trade J.*, **70**, 625, 1922). Translation of P. Bary's paper (*Chim. Ind.*, **7**, 640, 1922).

A CONTRIBUTION TO THE ANALYTICAL CHEMISTRY OF VANADIUM, WITH SPECIAL REFERENCE TO THE TESTING OF METALLURGICAL PRODUCTS.—H. Briefs (*Stahl Eis.*, **42**, 775, 1922). Deals with the separation of chromium and vanadium. A method is suggested for avoiding the ether process to separate iron and vanadium.

CALCULATION OF THE OSMOTIC AND ACTIVITY FUNCTIONS IN SOLUTIONS OF UNI-UNIVALENT SALTS.—J. N. Brönsted (*J. Amer. Chem. Soc.*, **44**, 938, 1922).

PATENTS.

DECOMPOSITION OF SILICATES.—G. A. Blanc (*Pat. J.*, 1,751, 1922). No. 181,677, Feb. 15, 1922. Silicates are decomposed by means of acids to give clear solutions of salts free from silica by the following method. Granulated leucite or other silicate is treated in a receptacle having a perforated base, with an acid solution which is circulated repeatedly by means of a pump and pipe. Soluble metallic salts such as those of potassium and aluminium are formed, and any colloidal silica which is also produced becomes occluded by the undissolved siliceous material in the receptacle. The supply of acid may be replenished from a tower above the receptacle. The solution is pumped to the top of the tower, where it falls on a grid and comes into contact with vapourous hydrochloric, nitric, or other acid. Liquid acids may also be used.

ALUMINA.—G. A. Blanc (*Pat. J.*, 1,753, 1922). No. 181,678, Feb. 15, 1922. A solution of alum is treated with ammonia under such conditions that the alumina is precipitated in a readily filterable form. The alum soln. is precipitated at a temp. near its ebullition point, the ammonia is added gradually and the liquor is subjected to constant agitation. Aqueous ammonia may be introduced into the alum solu. in the form of a spray, but preferably gaseous amm. is injected in order to utilize the heat of solution. After the removal of the alumina by filtration, the potassium and ammonium sulphates are separated by cristallization.

VIII.—HISTORICAL, EDUCATIONAL, INSTITUTIONS, HYGIENE, ETC.

INVESTIGATIONS ON CARBON MONOXIDE POISONING.—(*Coal Industry*, **5**, 96, 1922). In view of the fact that a certain evolution of CO has to be contended with in operating gas producers, the results of investigations conducted by the U.S. Bureau of Mines for determining and treating CO poisoning among those employed in mines, metallurgical plants, etc., are of some interest. Methods of collecting and preserving blood from affected persons have been investigated and developed. A superior method for the selection of analysis for colour work in chemistry has been developed. The solubility of CO in serum and plasma has been determined,

the amount of CO dissolved in the serum proving to have little effect on the accuracy of colorimetric determinations. In addition, Y. Henderson and W. Haggard, who have done work on the problem of eliminating CO from the blood after a dangerous degree of asphyxia, have determined that ventilation of the lungs could be increased from 300 to 400 per cent. by adding 6–10 per cent. of CO_2 to pure oxygen. They have also shown that the effects of CO on the heart are not specific, but are secondary to general asphyxia and a terminal failure of respiration.

THE CERAMIC INDUSTRY IN CHINA.—(*J. Soc. Chem. Ind.*, **41**, 2,93R, 1922). From *U.S. Com. Rep.*, Apr. 10, 1922. The industry has made little progress, primitive kilns and methods being still in use. Both the Government and the province of Kiangsi support a ceramic laboratory, but no attempt has been made at large-scale production. There are several undeveloped deposits of high-grade kaolin.

NOTE ON THE NATIONAL SCHOOL FOR CERAMICS, SEVRES.—(*Faenza*, **10**, 45, 1922).

EXAMINATION OF SOME ANCIENT CRETIAN POTTERY—(*Faenza*, **10**, 47, 1922).

PORCELAIN MANUFACTURE IN COLUMBIA.—(*Chem. Tr. J.*, **71**, 47, 1922). The manufacture of porcelain is increasing in Columbia. Colouring materials and small amounts of certain fluxes are imported. Clay and felspar deposits are worked near Pueblito.

THE DEVELOPMENT OF THE SWEDISH BRICK INDUSTRY.—(*Tonind. Ztg.*, **46**, 770, 1922). An account, by L. Anderson, of the development during the last 30–40 years.

CLAY MODELS 25,000 YEARS OLD.—(*Tonind. Ztg.*, **46**, 772, 1922). Shortly before the outbreak of the war, a remarkable discovery was made near St. Girons (S. France), at the foot of the Pyranees. In an almost inaccessible cavity in the rocks, two large clay images of bisons were found. Owing to the inaccessibility, and uniform temperature and humidity of the cave in the mountain side, the images have remained in practically the same condition as when modelled by artists of the Cro-Magnon race at least 25,000 years ago. The clay still retains its velvety touch and shows little evidence of cracking.

ARCHITECTURAL CERAMICS IN COLOGNE.—(*Tonind. Ztg.*, **46**, 571, 1922).

THE STONES OF LONDON : MARBLES.—J. V. Elsden and J. A. Howe (*Quarry*, **27**, 209, 1922).

ANCIENT POTTERY AND POTTERS.—Schiller (*Deut. Töp. Zieg. Ztg.*, **53**, 64, 1922).

THE CERAMIC INDUSTRY IN CHINA.—(*Pot. Gaz.*, **47**, 919, 1922). An extract from a report by the U.S. Trade Commissioner.

ART IN ARCHITECTURE.—(*Claywr.*, **77**, 541, 1922). A description of some examples of structures built of well burned brick, terra-cotta etc., in the U.S.A.

RESEARCH IN BRICK ARCHITECTURE.—(*Claywr.*, **77**, 554, 1922). The article discusses the development of architecture in the U.S. and the need of a better understanding in the use of clay products.

GOTHIC-MOORISH POTTERY IN S.E. FRANCE.—R. de Cabrens (*Faenza*, **10**, 25, 1922).

CHINESE CERAMIC ART.—S. Gorelli (*Faenza*, **10**, 36, 1922).

CHURCH BELLS OF PORCELAIN.—(*Sprech.*, **55**, 161, 1922). The Meissner Porcelain Works have succeeded, after lengthy trials, in making church bells of porcelain. A peel of 60 bells is to be installed in the city church of Meissen this Summer. The largest bell measures a little over 2 ft. 3 in. in height and has a diameter of about 1 ft. 8 in.

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